FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by R. W. V. PALMER

VOLUME XXXIII : NUMBER 1

Forestry in the Belgian Uplands
M. J. PENISTAN

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Forestry in Yorkshire
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The Inverness Excursion
The Scots Pine

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The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

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continued from inside front cover

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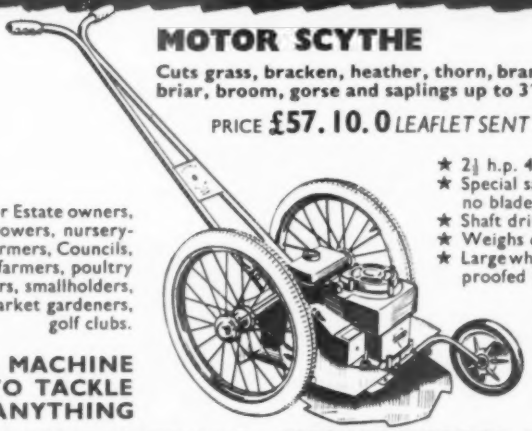

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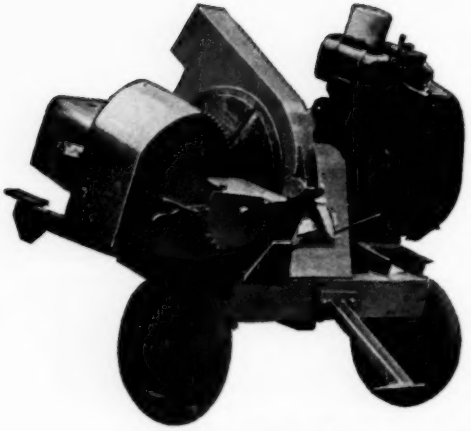

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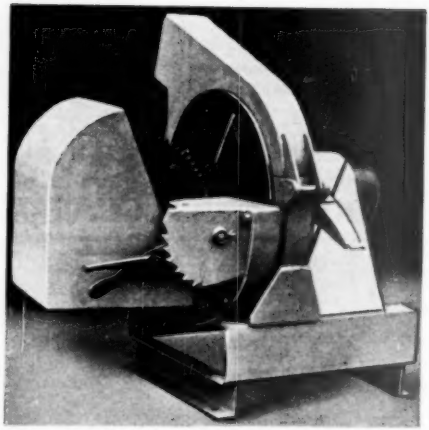

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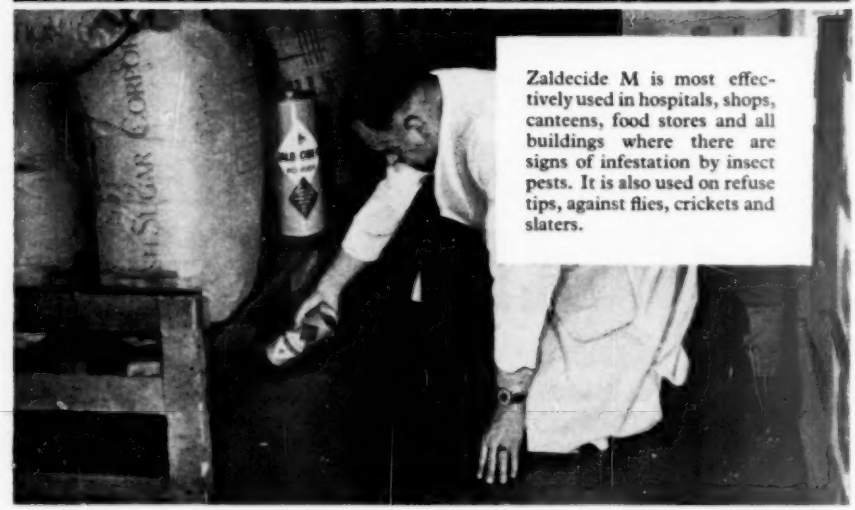

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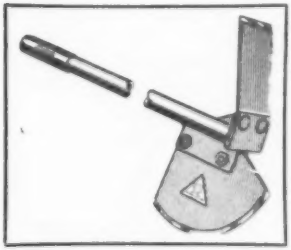

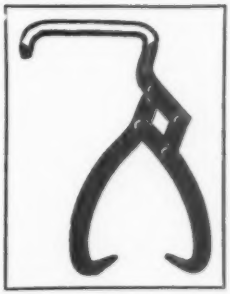

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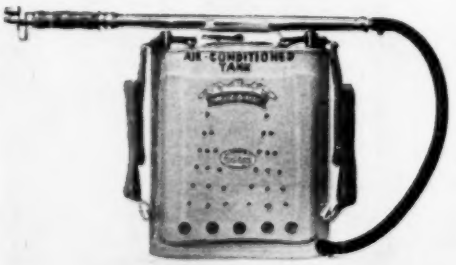

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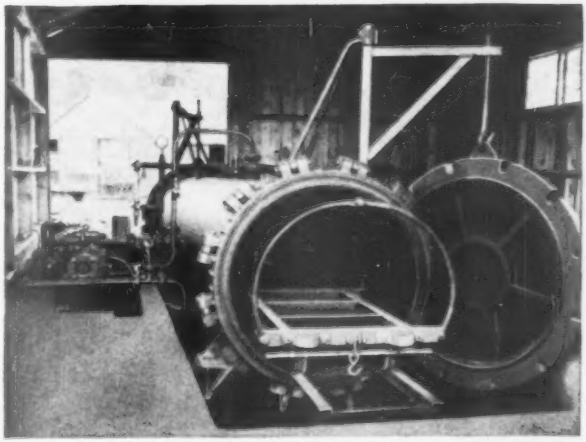

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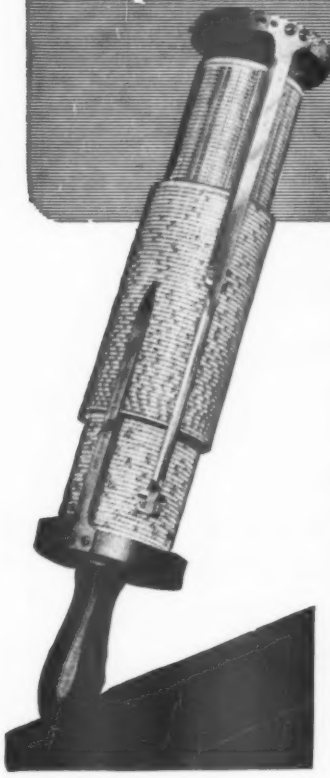

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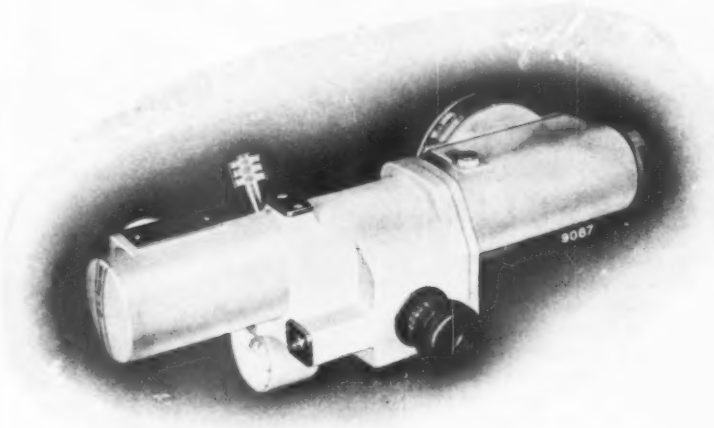

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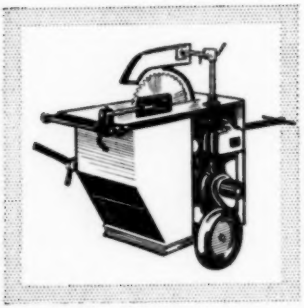

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FIG. 1. Transformation of spruce plantations. Forêt de Grand Bois, Vielsalm. The advanced stage of transformation in an 1880 plantation of Norway spruce. Half the old stand is felled and in patches, Anderson groups of the enriching species, here European silver fir, are well established. The ideal stocking is developing. Gradual removal of the old stand by patches will continue. Note the long crowns on the old spruces.

PLATE I

FORESTRY IN THE BELGIAN UPLANDS

By M. J. PENISTAN

(*Forestry Commission*)

SUMMARY

A brief general account of forestry in the region to be visited by the Society in May 1960. The native species are mentioned, but the account deals chiefly with the present conversion of coppice with standards to high, mixed forest, and the transformation of pure spruce plantations to mixed forest. The methods of achieving these ends are outlined.

1. *Introduction*

A FORESTER entering Belgium from Sedan at Bouillon is struck at once by the sudden change in the woodlands at the border from coppice with standards of poor oak, now in process of conversion by storing, to spruce high forest. The Norway spruce (*Picea abies*) becomes general and in the higher hilly regions appears at home. Plantation forestry has been practised for nearly a century, the main species being Norway spruce, and the main feature of Belgian forest practice today is the transformation of these plantations to stable high forest; a forest of mixed species and mixed age classes in small stands. Interested greatly by the account of the region by Anderson (1949), the writer was able in the course of a travelling fellowship to see a little of it in 1956, and to return to represent this Society at the annual excursion of the Société Royale Forestière de Belgique in 1958. What can be seen there is of the greatest interest to British foresters, and particularly to those who manage spruce plantations on the heavy soils above the older rocks of the hills of the west and north. Mixed forestry is, moreover, generally applied to all public forests today, so that methods are of general as well as particular interest and are applied to the poor sand areas of the Campine, to the lush loess of Brabant at Soignes, and to the difficult limestone foothills of Famenne.

2. *Areas and species today*

Belgium extends to 7·5 million acres, of which almost 20 per cent. is forested—1·5 million acres. Sixty per cent. of this is broadleaved, and only a quarter of this is high forest. Of the 600,000 acres of conifers, 60 per cent. is Norway spruce, 35 per cent. Scots pine (*Pinus sylvestris*), while the other species are very small proportions of Corsican pine (*P. nigra* var. *calabrica*), Austrian pine (*P. nigra* var. *austriaca*), Japanese larch (*Larix leptolepis*), and Douglas fir (*Pseudotsuga taxifolia*). In the region described, spruce is the main conifer, pines being used on the Campine and the Famenne chiefly. The chief broadleaf tree is oak (*Quercus petraea* and *Q. robur*), often as pure coppice.

In the uplands the proportion of wooded area is as high as 44·4 per cent. and in some districts (Bouillon and Florenville) it is higher (Anon., 1958).

3. *The region*

The southern part of Belgium is high-lying; an upland at 1,300 to 2,000 feet, rising slowly from west to east with the highest land against the Eiffel. The even gentle slopes of the upland are deeply cut by rivers, much more markedly in the west and the northern margins. Their lower levels are 600–700 feet above sea-level.

The rocks are primary—Silurian and Devonian chiefly, giving soils much like those of similar origins in Britain—generally heavy clay-loams but with freer sandy loams where sharper sandstones are found. To the south-west is a richer region of Jurassic rocks—La Gaume. Peat is general on the more gentle uplands. The main soils are brown-earths, somewhat degraded.

The climate increases in harshness eastward. In the Gaume it is gentle with some trouble from late frosts, but it can be harsh in winter in the Fagnes, and up to 40 days of lying snow can be expected. Within the uplands rainfall is above 36 inches and may rise to 50 inches per annum. Wind damage from the south-west has generally to be reckoned with and practice takes cognizance of this. Exposure nowhere limits tree growth.

The low Ardenne is the fringe area with sheltered, milder conditions but steep slopes, becoming in the south-west the special area of the Gaume. The main Ardenne has poorer soils, is higher and less dissected, with fairly extensive peaty areas, while the Hautes Fagnes are highest, most exposed, wettest, and have extensive *Molinia* areas in the open and, though most of their margins include low and sheltered ground, they are montane areas.

4. *The forests*

Ecologically the low Ardenne is an oak-hornbeam climax, which according to Galoux (1951) becomes an oakwood rich in beech at 1,000–1,200 feet. The high Ardenne and the mineral soils of the Hautes Fagnes are considered by him climax beechwoods (*Fagetum/Querceto-carpinetum*). No conifers are natural. *Abies alba* is thought to be natural by some in Hertogenwald, but Herbignat (1946) does not rate it so.

The effect of policy and practice has, in the past, led to the almost universal practice of coppice working, with or without standards (usually the latter), though standards have always been grown on better soils and especially in the Gaume. The coming of independence to Belgium and the need to develop intensively the land use in balance with agriculture has led, in the latter half of the nineteenth century, to the afforestation of poor uplands not really suitable for farming, and to the continuous development of high forest from coppice working. There are, however, still considerable coppice areas on steep slopes, near towns, and where sporting has value and influence, and here progress until lately has been slow. The success of spruce plantations and their paying utilization has led to a boom in spruce planting by private investors which extends across the boundary into the French Ardenne, a region not yet greatly developed, where land is very cheap.

Generally the conversion on lower ground is to mixed oak and beech (*Fagus silvatica*) by group planting and storing, but a good proportion of conifers is

prescribed. So far Norway spruce has been pre-eminent. It was planted pure on low and high ground over very large areas, though in the Hautes Fagnes while they were in German hands (1875–1918) line mixtures of Scots pine and spruce were used. Turf planting was, of course, general, and it was from Hertogenwald that Sir John Stirling Maxwell introduced this method to Scottish and eventually British practice. (The hand methods he describes are still in use—mechanical ploughing has not been adopted.) In the State forests, however, there are arboreta in which a very wide variety of conifers has been planted, and which now give a valuable guide to foresters who are dealing with the spruce plantations.

Norway spruce has grown generally very well. A number of strains have been used. Some of the finest stands (P. 1864 at Losheimergraben in the Hautes Fagnes) contain wonderful columnar spruces with comb-branching and have been selected for breeding by Swedish foresters. The stands are very well thinned. Crown thinning is universal and there is a multi-storied, uneven canopy in pole woods. The observed stocking fell well below that of British Yield Tables, and reflects a height spacing ratio of 23 per cent. Considering this is a crown thinning, the predominants are well spaced, but old stands generally carried 150 stems per acre.

There has been relatively little trouble from pests. *Ips typographus* was rife in shell-damaged areas after 1944–5, but was cleared up effectively by thinning and felling without the general destruction necessary in the Vosges. There is no history of serious defoliators, though Anderson in 1948 mentions a sawfly. *Dendroctonus micans* has removed Sitka spruce (*Picea sitchensis*), but was not seen on Norway spruce. The effect of game can be serious. Stalking is very valuable and the Royal Forests (and others) tend to be very well stocked with deer, red and roe. In the Hautes Fagnes the severe winter leads to bark stripping and generally young trees, especially of introduced species, are heavily browsed.

The greatest tangible difficulty attending spruce growing is *Fomes* butt rot (*la pourriture rouge*) which becomes rife in second generation stands, and this has led to the present-day policy and practice. Wind troubles have already been mentioned.

Norway spruce regenerates freely in the Hautes Fagnes and High Ardenne. Lower Ardenne stands do not. As in the Southern Uplands of Scotland on similar sites, spruce grows away very slowly when planted in clearings, due chiefly to its inability to compete with the strong invasion of *Aira flexuosa* and other grasses.

Of other exotics, Douglas fir gives promise. Provenances west of the Cascades are specified. Its use is rather optimistic sometimes, and *Phomopsis* cankers can be seen in higher plantings. Japanese larch is established as a useful, versatile, and vigorous grower. *Abies alba* has been grown on a small scale and with success at high and lower levels (down to 1,000 feet). It regenerates freely. *A. grandis* is also valued. Of broadleaves, the red American oak (*Quercus borealis*) is fancied for enriching stored coppice in the low Ardenne. *Prunus serotina* is generally used on light soils of the lowlands as a deer-resistant site-improver. It regenerates copiously.

5. *Practice*

(*a*) *Policy*. The general aim is to improve the productivity of all broadleaf areas, converting coppice to broadleaf or mixed high forest. The existing conifer areas

are to be stabilized, production being ensured by so arranging stands of small areas that ages are intimately mixed, and by diversifying species to guard against soil degradation and the general spread of butt rot. The proportion of broadleaf to conifer in the low Ardenne is to be 50 per cent., in the high Ardenne 25 per cent., and in the Hautes Fagnes 10–20 per cent. Natural regeneration is to be the eventual means of restocking, and as a general rule, Norway spruce will retain a major role where it regenerates well. In spite of its general good quality and its ready sale, continuing management of pure Norway spruce by clear felling and replanting in sites where it will not regenerate naturally is not to be done, and it is interesting to find in all forests managed by the State mixed forestry by age and species is the rule.

This policy was drawn up by M. Turner, the last Director-General, who had a long personal experience of spruce in the high Ardenne. He was so convinced of the need for enlightened silviculture that he decreed that, while plantations were being diversified, treatment should be intensive and free of volume production considerations. The great thing was for diversification to proceed steadily and as site and circumstance dictated. Recently the present Director-General, M. Herbignat, has decreed that, in diversification at least, progress shall be planned to give roughly equal volume coupes during the period of treatment. The procedure is still, however, to prescribe treatments, then to estimate the volume outturn, and then to arrange the work to give as equal annual yields as possible.

(*b*) *Management.* Two main processes are in progress in the woods. The first is conversion. This involves a change of system—from coppice or coppice with standards to high forest. It is naturally confined to the low Ardenne and lowest parts of other regions.

The process in simple coppice has been described by Houins (1957) for the Bouillon District. Straightforward storing of coppice is disliked as it gives an inferior oak high forest on coppice stools, and perpetuates the present rather degraded condition of the forest soil. Where the coppice is strong and form good at rotation age (20–25 years), and some 24–30 feet high, crown thinning to the best stems is carried out, but to an uneven degree. The period of conversion is 24 years and these stands will be thinned every 3 or 6 years, introducing $\frac{1}{8}$-acre groups of beech in thinner patches of the uneven treatment. At 24 years the stand should show dense and open zones, the open ones interplanted with beech groups so that at 45–50 years there will be 25 per cent. beech and 75 per cent. oak.

Poorer coppice will similarly be crown thinned and patch planted, but the poor patches invaded by undergrowth are cleared in $\frac{1}{2}$-acre to $\frac{3}{4}$-acre patches depending whether spruce or Japanese larch is planted. Heathery patches may be planted with Scots pine. In the better soils where oak is of poor form it is either underplanted after opening out with Douglas fir or is cut in strips and five rows of Douglas planted. The treatment is not normally throughout the whole area but in patches, the desirable distribution of ages and species being achieved in this way, by spot planting.

Mixed coppice is similarly treated, beech areas being underplanted with *Abies grandis* and *A. alba*. Beech is carefully preserved to give seedlings.

Pure hornbeam coppice (*Carpinus betulus*) is stored by progressive reduction of stems per stool on a 6-year cycle, and gradually weakened. At the first cycle groups of tolerant trees are planted—*Abies* species, followed in turn by Douglas fir and then spruce. Larch may finally be planted in clearings.

Some 4,000 acres have been so treated in Bouillon under the enthusiastic direction of M. Poincelet, the *inspecteur*.

Coppice with standards in the Gaume, as at Izel and Jamoigne, has been successively stored and thinned. Where soils are suitable, beech has been favoured and regeneration encouraged in groups. Oak, sycamore (*Acer pseudoplatanus*), and ash (*Fraxinus excelsior*) form useful mixtures. When conversion to even stands is achieved 'this is modified as far as possible to a mixed group selection aspect, a method which enables the best to be made of soil and climate . . . to ensure as much regeneration as possible and to introduce eventually groups of other species to raise yields without leaving too far the ecological climax' (Anon., 1958).

These irregular broadleaf and mixed forests, converted from coppice, are not disjointed and whimsical collections of stands. They are well-stocked forests being resolutely and knowingly handled by perceptive officers. The control is tight and management efficient. Some are already controlled by successive enumerations, a method which will become general as conversion is completed.

In contrast to the conversion of coppice, there is the diversification of high forest—usually of spruce, but also of broadleaves. This operation is known as *transformation*. It was codified in a directive of 1957, which lays down the minimum areas to be treated and the form plans are to take. In most cases a total or partial change of species is prescribed running concurrently with a break-up of even-aged stands, leading towards a better biological balance and securing an improvement of hygiene and sustention. It consists of a succession of fellings, sometimes in the form of small clearings or sometimes of a double coupe, the first partial, the second final, which secure the successive substitution in groups of a stocking better adapted to the site over all or part of a plantation. The transformation of a whole plantation is not always prescribed, areas which are considered ecologically stable (self-regenerating spruce, for example) may be left untreated to form part of the emerging forest.

A plan is drawn up for compartments to be diversified. It should be made for each block of plantations and prescribe the period (usually rotation age *minus* 30 years, say years 50–80); the areas to be treated in sub-periods; the species to be used, their percentage and the order of introduction; the extent, shape, orientation, and distribution of the groups of each species, and the method of planting; the yield from transformation coupes (usually by Cotta's formula, or by numbers of trees).

Two forms of group plantings are prescribed. Economic or production groups will be, in this order of importance, of beech, sycamore, red oak, and native oak where broadleaves are concerned, and of Douglas fir, *Abies grandis*, *A. alba*, *Tsuga heterophylla*, Norway spruce, the larches, and pines. It must be remembered that the complete exclusion or replacement of Norway spruce is not proposed. Except where conditions are completely unsuitable it will be planted, especially in the absence of regeneration, towards the end of the transformation period.

Conifer groups will usually be $\frac{1}{10}$ to $\frac{1}{5}$ acre for tolerant trees, and clearings larger than $1\frac{1}{4}$ acres for intolerant are not allowed. Nothing exact is prescribed, the area and distribution of groups must depend on local conditions and the species used. The number of groups can usually be got quickly from the annual coupe divided by the size of groups. Planting will usually begin in blanks or wind-blows. Groups will be circular or elliptic with the long axis north-west to south-east for wind firmness and shade.

The second type of group is the biological planting. This consists generally of the advance planting of small areas of $\frac{1}{40}$ to $\frac{1}{20}$ acre in proposed groups. Anderson group planting may be used here, but this method has been generally abandoned until the results of early plantings in M. Turner's old district of Vielsalm have shown their worth.

The method of transformation has now been well tried. M. Turner's classical group working with $\frac{1}{4}$-acre groups at two per $2\frac{1}{2}$ acres and gradual expansion by regeneration and planting with varying shelter wood provided by high and low thinning, has been applied elsewhere with varying results. See Anderson, 1949, and Antoine, 1954. The group cut is a circle of 20 yards radius. The first felling is on a 4-yard band on the diameter running WNW–ESE., reserving four or five of the best trees. This is fenced against deer. Twenty-four Anderson groups (cellules) of silver fir or thirty-seven of beech are planted in the belt. All dominated stems in the southern half of the group are cut to let in the light to the planted band. North of the band a heavy high thinning is made to control weeds. The felling will proceed northwards with further planting, at 12-year intervals, and, if regeneration comes, southward. Low thinnings are made on the east side to allow light to the plantings. It has too much virtuosity for general use, but simpler and effective local variants are in general application. Least success has followed formally spaced group cutting on the Hautes Fagnes where wind-falls have caused unwanted extensions. Here transformation (of age structure more than species) has followed snow and wind clearings and regeneration by shelterwood strip fellings is more successful. Today the effect of transformation is general, and strikingly successful, a compliment to good thinning and general stand stability, and bold but wise working. There are no misgivings over sale or extraction difficulties. Roads are good and the buyers of timber well equipped and skilful.

(*c*) *Control.* The method of securing this diverse treatment and complication of structure and composition of the forest is simple and effective. Although volume considerations affect the planning to some degree the work is controlled by area. Thus each charge, we would say beat or section, is sub-divided into blocks, each of four sub-blocks, often compartments. There are thus twelve sub-divisions. Treatment cycles are in multiples of 3 years. Each block is visited in turn and one of its sub-divisions treated intensively (groups cut); at the same time any urgent treatment in the other three sub-divisions is done. Next year it will be the turn of a sub-division of the next block. There is thus a coverage of the whole forest in 12 years with optional treatment at intervals of 3 years ('rotation de douze ans avec passage facultative de six et trois'). Thus young areas are treated every 3 years, older every 6, and the oldest every 12. Nothing is overlooked and a very effective

FIG. 2. Transformation of spruce plantations. Forêt de Grand Bois. Group cut in 40 year old Norway spruce according to M. Turner's prescription and planted with groups of beech; seen from low thinned SE side with Norway spruce regeneration in foreground. Note excellent crown development which makes opening to this degree possible.

FIG. 3. Transformation of spruce plantations. Forêt de Grand Bois. Norway spruce planted 1880. Transformation begun in 1938 by planting *cellules* (Anderson groups) of beech in anticipation of a good spruce seed year. Photo in 1956 shows groups coalesced and new mixed stand in thicket stage. Some of the old stand in the middle lost by windfall.

PLATE II

control is kept of the work in hand. The method has great application in this country.

The passage of 12, 6, and 3 years is normal in conifer areas and mixed. In broadleaves it is sometimes 16, 8, and 4 years, while the Bouillon conversion cycle is 24, 12, 6, and 3 years. Not only is this method effective, but in spite of the intensity of working the costs of supervision in the forests seen was near that of the French Administration in the Vosges, and one-third of that in Germany, Denmark, or, for that matter, Britain. The greatest respect is due, therefore, to the officers engaged in this enlightened forest management.

6. *Protection*

The threat of deer to young plantations has been mentioned. The stocking of deer in Hertogenwald (Hautes Fagnes) in 1956 was one red to 62 acres and one roe to 150 acres. The marginal stocking in Bouillon, according to M. Poincelet, who had one beast to 35 acres, was, for beech one beast to 70 acres in big clearings; at one to 170 acres all species have a chance, but for groups one to 250 acres is the level. In Bouillon stalking lets at £2 per acre per annum. This high stocking leads to the use of enclosures, usually quite small (embracing one or two groups), fenced with pig netting 6 feet wide with a mesh of 12 inches by 8 inches on light spruce poles at a cost of £2. 10*s*. per group or £10 per acre. Spruce regeneration is also protected against browsing with arbinol, every fifth tree being treated for 18*s*. per 100 trees. Rabbits are very rare and no protection measures are needed. No treatment of stumps was seen against *Fomes annosus*.

7. *Acknowledgements*

Thanks are due first to the Forestry Commission and the Nuffield Foundation who made the first visit possible, and the Société Royale Forestière de Belgique for the second. Thereafter the officers of the Administration des Eaux et Forêts who so kindly showed their work, must be thanked and congratulated. Finally, the help of M. Brouhier, Secretary of the Société Royale, must be acknowledged in providing recent literature.

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SHELTER NEEDS IN RELATION TO LAND USE[1]

By J. E. NICHOLS

(*Milford Professor of Agriculture, University College of Wales, Aberystwyth*)

SUMMARY

The needs of stock and crops are not necessarily the same in time and space. The greatest single contribution to total shelter is the configuration of the land itself (geomorphic shelter) while the contribution of other topographic shelter such as heather, low bushes, even rushes, walls, hedges, and buildings is considerable.

Forest shelter should be thought of as added shelter and related to the distribution of exposure risks over the farm as a whole. Its value may be greatest, provided space can be allotted, where stock has to be concentrated at critical times and cannot therefore make use of geomorphic shelter.

We have still much to learn about the nature of plant and animal responses to exposure risks and the shelter needs of a particular area or farm must be assessed from a case study involving exposure risks, existing shelter, and husbandry methods obtaining or proposed, before any scheme is undertaken to provide added forest shelter.

THE concept of 'shelter' in agriculture involves those of 'exposure' to adverse climatic influences, on the one hand, and of reactions inimical to the well being and production of crops and stock, on the other. All include complicated series of interactions of many factors, for the most part interrelated and not independent of each other. The problems of shelter resist precise expression, and in spite of the very considerable amount of research and observation which has been applied to define their components, in many countries and over wide ranges of conditions, as well as of the accumulated experience regarding shelter and its effects, there is as yet a dearth of critical evidence to act as a foundation for guidance on specific needs for, or provision of, shelter. Moreover, adverse effects of 'exposure' grade from the negligible to the catastrophic, so that over much of their range they cannot be assessed in economic terms. The provision of shelter to lessen exposure risks, or to reduce exposure effects, is an attempt to mitigate or modify the major uncontrollable segment of the environment of plants and livestock under their particular local circumstances, i.e. in the particular habitat to which they are confined by farming practice.

A further difficulty with regard to shelter in agriculture arises from the general position that the needs of stock and crops are not necessarily the same in time and space; within a farm, with the major obvious exception of grassland, animals and actively growing plants are not ordinarily on the same piece of ground together; and what may be protective shelter to a young crop in early spring may be deleterious shade later on, though for stock what may be shelter in the colder and wetter months may also give useful shade in summer. Also, widely dispersed trees,

[1] Based on a paper read before the British Association for the Advancement of Science, York, 4 Sept. 1959.

very open woodlands, are a well-recognized nuisance in crop husbandry, though they may be an asset on stock farming land.

Six years ago, before this same Section of the Association, in discussing shelter-belts in relation to hill farming, I called attention to the need for more critical investigation on belts and their effects in crop and stock husbandry (Nichols, 1955). In the last few years wide studies of shelter problem have been made under the aegis of the Agricultural Improvement Councils and researches encouraged at several centres, including Aberystwyth. Though the work on the agricultural aspects is still in its very early stages, some general observations can be made to extend the earlier ideas and tentative conclusions to meet the scope of the present title.

Forest shelter, which is taken to mean that provided by plantations of various forms, occupies space; hence it is more suited to areas where the value and productivity of the land are relatively low, e.g. in the upland and hill regions where stock farming is the major enterprise and cropping is subsidiary to it, or to other areas, e.g. the Downs, the Cotswolds, parts of East Anglia, &c., where the land, crops, and stock are likely to suffer from exposure to severe winds and weather conditions. Throughout these areas there are very wide ranges of husbandry systems, of variations in local environments, and of farm sizes, so that obviously no hard and fast rules can be observed in deciding on what kind, or amount of shelter, if any, is needed. Each holding must have its own peculiar problems.

A basic consideration, however, is that forest shelter should be primarily regarded as *added* shelter, that is it can only contribute an addition to the total shelter provided from other sources. The importance or value of this contribution to a holding may be small overall, although it may be significant in its effect on a restricted area of the farm, for instance around the buildings, or on inbye land. If wind is taken as a major adverse influence, then a considerable amount of 'shelter' on any area is provided by the form or configuration of the land itself—which can well be termed, as suggested by Hogg (1959), 'geomorphic shelter', and can be assessed as $100\left(1-\frac{\text{sheltered wind speed}}{\text{exposed wind speed}}\right)$. There is plenty of practical experience to suggest that geomorphic shelter makes the greatest contribution to total shelter over many of the upland and hill areas, especially on land above the planting limit. It is enhanced by irregularities of the land surface and, as is well appreciated by anyone who has observed movements of stock, especially sheep, this form of shelter is the first to be adopted when weather conditions become unfavourable. Moreover, the land surface effects—the total geomorphic shelter—are increased by the drag effect in which wind speed near the ground is greatly reduced. Observations made near Aberystwyth clearly show that within the overall geomorphic shelter, there is more relative shelter at 1 foot above ground-level than at 2 ft. 6 in., the significance of which, to sheep and lambs, may be very great, if one remembers the ability of animals to move and to change their postures. These observations not only confirm general experience but also emphasize the point that to recognize the importance of this form of shelter is to have possibly a different approach to shelter needs. Also, effects of vegetation 'screens',

as in heather, low bushes, even rushes—partially recognized in practice—may be more appreciable than is commonly thought, in giving distributed shelter near ground-level.

Other contributions to the total 'topographic shelter' come from barriers and screens, such as walls, hedges, and buildings, which have been erected, generally, for other purposes, i.e. in relation to land and farm management. Forest shelter, added to that so available, may, on the one hand, make a great contribution to valuable shelter to parts of the farm which have restricted use in time, or where stock may be heavily concentrated at critical periods, provided that the area taken up by plantations is not excessive compared with that needed for farm purposes. On the other hand, forest shelter may not be required if temporary, and strictly local, additional shelter can be given more directly otherwise; for instance by straw bales in lambing fields.

The need, then, for added forest shelter on a farm is related to the distribution of exposure risks over the farm as a whole and is affected by the ways and periods during which different parts of the farm are used. There is considerable scope for further, more critical, investigation of both the nature of plant and animal responses to adverse environmental conditions and the incidence and frequency of occurrence of the adverse factors. It is interesting to note that much work on shelter problems is now being carried out along the approach to exposure problems. The main questions here seem to be, can exposure be assessed and expressed in terms which can apply to specific areas, can the risks be estimated?

It is simple and obvious to suggest that a great amount of survey work, involving much instrumentation, will be needed before such questions can be reasonably answered; but for the extensive areas and ranges of conditions concerned this cannot be regarded as practicable at this stage. Attempts are therefore being made to use cruder methods of estimation, e.g. by studies of plant growth deformation (Thomas, 1958), by ecological studies (as at King's College, Newcastle), by flag tattering techniques (as at Aberystwyth) (Thomas, 1959), as well as by meteorological observations (including use of the katathermometer) and by recording animal reactions and losses at critical periods. In this connexion, distinction must be made, if possible, between short- and long-term or cumulative effects, and more knowledge gained on the degrees of risk of, or tolerance to, exposure at various stages of plant and animal growth. For example, there is a cycle of physiological states and events in livestock which gives rise to varying degrees of stress and thresholds of risk; in adults, late pregnancy, parturition, and lactation; in the young, birth and the early postnatal days, and weaning, are highly susceptible periods, during which some form of protection is advantageous to well-being, whether it is provided in housing or husbandry methods or by shelter. With sheep it is the flock as a whole which is the unit of management for the greatest part of the year, and adult sheep are exposed to an additional critical period, of short duration, by shearing; hence added forest shelter might well be more justified to lessen exposure risks when and where the flock is concentrated than where it is grazing with access to geomorphic and other topographic shelter. The shelter pattern is related to the patterns of husbandry, of grazing behaviour and of flock

response to untoward weather; experience and observation indicate that while individual animals vary greatly in their responses, weather changes evoke collective responses—a form of 'flock turbulence' occurs.

Instances of the sensitivity of stock to weather changes and of their use of mainly geomorphic shelter have been noted in the course of field observations during the early summer of 1959. The movements were recorded of a flock of about 250 ewes and lambs grazing a field of about 20 acres situated on an exposed undulating plateau near Aberystwyth. Meteorological and anemometer records were taken at 'exposed' and 'sheltered' positions, standard flags having shown three times as much tattering at the 'exposed' as at the 'sheltered' sites. Another part of the field provided geomorphic plus vegetation (gorse and fern) shelter. On an occasion when a warm front, with less cloudiness, approached, the flock moved from shelter to exposed ground as the temperature rose from 45° to 50° F., and the wind speed (at 2 ft. 6 in. above ground-level) dropped from 20 to 10 ft./sec. (*c.* 14 to 7 m.p.h.). During a series of observations, over 4 days, when the mean temperatures ranged from 48° to 54° F., the sheep moved to sheltered areas when katathermometer readings exceeded 40 mcal./sq. cm./sec. (cooling power greater), with wind speeds between 22 and 34 ft./sec. They tended to stay on the exposed parts of the field when conditions were steadier, with katathermometer readings below 20 mcal./sq. cm./sec., wind below 20 ft./sec., and temperatures 55°–58° F. On other occasions, when conditions were favourable, over 30 per cent. of the flock stayed on exposed areas of the field; as more adverse conditions came, this proportion fell to 20 per cent., with between 5 and 34 per cent. being on the geomorphic shelter area, and the rest of the flock on the other parts of the field where gorse and bracken gave additional shelter.

The above considerations do not only apply where stock-carrying capacity is relatively low for the land as a whole, i.e. in the hill farming areas. In the mixed stock farming regions such as those near the western coasts, where farms and fields are small, the problem is to give shelter to sheep throughout the winter months (including 'tack' or 'wintering' flocks) and to cattle in summer. Here the traditional, but now often neglected, stone and earth bank with hedge on top may well be the most appropriate shelter for both sizes and kinds of stock throughout the year, and give protection from all directions.

It is well known that the milking cow is very sensitive to weather changes. Practical experience in dairying areas where the herd is kept outside at grass shows the benefit of planted shelter, and the use of tree windbreaks around small grazing paddocks is well illustrated in New Zealand. Marked falls in milk yield can follow exposure to adverse weather even where the herd is housed at nights and let out daily for a few hours for exercise, as is the common practice in Great Britain during the winter months; losses of 10 per cent. or so in milk yield are not uncommon and are significant economically.

The critical conditions are not clearly defined, but from preliminary studies by Moger (1958) at Aberystwyth, it would seem that they vary according to season and to the cows' acclimatization to preceding weather. For example, during early winter, with cattle housed at night, sudden drops in temperature, to daily

means below 40° F. and minima below 32° F., initiate declines in yield and the onset of windy, rainy weather later further affects yield; in spring, with the cattle outside and grazing young grass, during a warm spell, it was not until a fall in night temperature of 10° (from 49° to 39° F.), combined with moderate wind speeds of about 8 m.p.h. and rain, occurred that yields markedly declined. Relatively little topographic shelter was available; some added shelter might well be advantageous to mitigate the weather influences.

Such evidence is only indicative at best but tends to support the broad conclusions to be drawn from the general considerations outlined, that the shelter needs of a particular area or farm must be assessed from a case study involving exposure risks, existing shelter, and husbandry methods under the systems of land use obtaining or proposed, before any scheme is undertaken to provide added forest shelter.

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FORESTRY AND LANDSCAPE IN THE EXMOOR NATIONAL PARK[1]

By ROGER MILES

SUMMARY

To safeguard scenery and other amenities and to win sympathy for forestry, the writer advocates a much profounder approach to proposals for afforestation. These should not be considered piecemeal nor separately from other possible developments, but each region of importance should have its own comprehensive landscape development plan drawn up to conform with certain guiding principles. Having been entrusted with the preparation of such a plan for the Exmoor National Park, the writer uses this as an example and enunciates briefly the ten principles which guided him in its preparation. He then explains, without giving details of particular areas, their effect on the size, shape, and constitution of the afforestation which he felt able finally to propose for the area.

IN 1955 this Society framed its Annual Excursion around the subject of 'Amenity and Forestry'. The area chosen for field study and discussion was the Lake District, and the reconciliation of large-scale forestry undertakings with landscape beauty was most carefully considered. Afterwards, T. E. Edwardson (1956), writing in *Forestry*, recorded that members tacitly agreed to the application in the forester's art of three guiding principles, namely naturalness, gradualness, and reasonableness.

Although I was not on that Excursion, I read the account of it with very great interest and agreed wholeheartedly with the principles which were enumerated. As a Planning Officer, whose particular concern is for the future appearance of landscape, it is necessary for me to devote a great deal of my time endeavouring to marry the economic needs of forestry with the aesthetic needs of the public. It was, therefore, very encouraging to read that the members of this Society, who might naturally be expected to have a strong forestry bias, were prepared to consider such a wide variety of concessions in the interests of amenity. Unfortunately, a similar willingness in the public, who frequently profess deep concern for the landscape, to consider making concessions in the interests of forestry, is seldom to be found. But it is my belief that Local Planning Authorities can help very materially to further the interests of both the national forestry programme and the protection of beautiful scenery by acting as co-ordinating agents between apparently conflicting points of view.

In my county there is the whole of the Quantock Hills notified as an 'Area of Outstanding Natural Beauty' and the bulk of the Exmoor National Park. I have the good fortune to serve the Committees who administer these places. In such areas as these where demands for industry and housing are usually small, forestry proposals may often be the only proposals which are capable of affecting, on a large scale, the pattern of the landscape.

For a number of years I have felt that the customary practice of considering

[1] Based on a paper read at the Society's meeting at Inverness in September 1959.

the local impact upon the landscape of each forestry proposal, particularly of each new afforestation proposal, as and when it occurred, was not the best way to safeguard the scenery involved, or, indeed, to win public sympathy for forestry. It seemed to me that such proposals should be considered against a regional background and that areas such as National Parks should each have a kind of landscape development plan.

In such plans the qualities of landscape would be precisely defined and the needs of forestry would be carefully considered, together with those of all other land uses or interests, so that it would be possible to indicate where and how afforestation would contribute to, or detract from, the scenic beauty. The possibilities of integrating forestry with other activities in the area would also emerge.

Twelve months or so ago an opportunity was given to me to put these ideas to a test. My Committee agreed that I should undertake a survey of the Exmoor National Park with a view to formulating a plan of the type described.

I decided that the basis of my survey should be as exhaustive a study as possible of the physical and aesthetic qualities of the landscape. It was necessary first to record the basic factors, such as climate, soils, vegetation, and the like, which had combined to provide the scene before me. What was more difficult, but just as essential, was that I had to try to understand how and why the colour, shape, and arrangement of the components in each scene combined to make it attractive or unattractive as the case might be. In my opinion, only after acquiring some perception into these matters would useful ideas be formed in my mind about the possible effects, whether good or bad, which the introduction of new woods might have upon these scenes.

It quickly became apparent in my survey that the scenery in the Exmoor National Park may be divided into five broadly distinct areas. These are named for convenience and described very briefly below:

1. *The Brendon Hills.* Roughly the eastern quarter of the Park area and an outlier to the main Exmoor plateau. The northern slopes of the Hills rise steeply and support considerable areas of woodland and most of the State forestry in the Park. The southerly gradients are gentle and are almost entirely agricultural, being divided into neat fields, characteristically bounded by banks topped with beech hedges. There is not much open moorland, and trim orderliness and maximum husbandry are dominant notes in the scenery which is generally unpretentious.

2. *The East Central Belt.* A belt of country containing a transitional landscape between the agricultural pattern of the Brendons to the east and the moorland wildness of Exmoor to the west. Both types of scenery either mingle or contrast sharply here and the variety of effect is very rich. Extensively wooded river valleys are notable in this area and provide landscape features of great beauty.

3. *Exmoor Forest.* The parish of Exmoor which is virtually contiguous with the old Royal Forest and is now the heart of the National Park. A high-lying, uncluttered windswept landscape of rolling grassy hills and steep-sided hidden combes. Traditionally, the area has been almost treeless for centuries, the only major grouping of small woods being around Simonsbath. The primary land use

is sheep farming with extensive sheep walks over the bulk of the land which is classified as marginal. The gentle subtlety of colouring and texture and the great simplicity of the scenery are among its special qualities.

4. *The Coastal Strip.* High cliffs, clothed practically to the beaches with trees, provide one of the finest lengths of wooded coastline in the country. Small towns and villages are frequent and sizeable in this section and there are good roads commanding extensive views over the Forest. The presence of fine heather moors and special landscape features, such as Watersmeet and the Valley of Rocks, add to the esteem in which this part of the Park is held.

5. *The South-West Fringe.* From the southern edge of the Exmoor plateau a pattern of foothills and scrub-scattered valleys may be seen sloping southwards, becoming increasingly agricultural or wooded, until it meets a great expanse of rural Devon which stretches away beyond the Park boundary. In this fringe the scenery is introductory to the highlands above and cannot be compared with them in landscape merit.

In my survey of these landscape types I tried to measure the contribution which each woodland made to the landscape wherein it was situated. The parts played by the size, shape, siting, and crop composition were of the greatest importance in deciding whether the wood had a good or bad effect in the scenery. In particular the effects achieved by various species and arrangements of conifers required careful observation, in view of the national need for this type of tree and the fact that only conifers would be capable of producing satisfactory timber under the upland conditions of most of the area which was being studied.

In beginning to consider the siting of new woods it was necessary to remember also the problems of management, such as accessibility, which would have effects upon the economics of my scheme from a purely forestry point of view. In these matters it was finally concluded that some compromise was required at times, but this point will be referred to again later.

The next step was to consider the integration of forestry with other land uses and interests in the Park. The primary land use in Exmoor is agriculture and the findings of the Zuckerman (1957) Report upon Forestry, Agriculture, and Marginal Land were firmly in my mind at the time of my survey. When agriculture and forestry are carefully integrated as partners in an area of marginal land each may benefit the other in a number of ways. But it was felt that, in Exmoor Forest at least, the very high amenity value and the special aesthetic qualities of the existing scenery must be granted primacy, more often than not, over any large-scale afforestation possibilities which might be argued favourably from the standpoint of integration with agriculture. It seemed to me, however, that a not unreasonable case could be made in favour of some quite substantial afforestation in a few places in the distant views. The siting and design of the plantations would need the greatest care, but they might be employed to emphasize otherwise blurred outlines, to create new landmarks, or to dramatize a scene in which repetition threatened to become monotonous. However, that is a very personal opinion and I do not think that public opinion at present would agree with those points.

Generally, I came to the conclusion that visual and functional integration could be best achieved where plantations were sited on intermediate slopes in the landscape. Placed thus, the new woods would shelter the farms below and be transitional in scale between them and the open highlands above.

The movements and preferences of visitors to the Park had also to be studied. The tourist trade plays an extremely important part in the economy of National Parks and, of course, these areas were designated under the National Parks Act of 1949 'for the purpose of promoting their enjoyment by the public'. It was found that tourist-choice generally varied according to quality of landscape, accessibility, and facilities available. Where these three factors were favourable and occurred together the greatest volume of tourist traffic would be concentrated. The Coastal Strip, undoubtedly, attracts visitors in the greatest numbers. At the same time, the tastes of a minority who prefer the quiet places could not be forgotten but their movements were less easy to define.

In similar ways in my survey consideration was given to the needs of other interests in the land of the Park and information was recorded about the activities of the Nature Conservancy, local Naturalist Societies, and Water Authorities. Traditional sports such as riding, hunting, and fishing and their special requirements were noted with the object in each case of seeking ways and means by which conflict, if it existed at all, between forestry and these interests might be minimized.

Upon analysing the information which had been collected in the survey, a number of broad principles suggested themselves as guides in the process of selecting sites where afforestation would be acceptable in the National Park. Thus, I was led to the conclusions that (in Exmoor at least) an afforestation proposal may be considered favourably so long as:

1. It will not alter drastically the existing character of popular beauty spots or the fringes of tourist routes. (But some beauty spots or tourist routes may be improved by limited tree planting.)

2. It will not obstruct the panoramic views obtained from popular viewing points. (Yet some viewing points may benefit from limited tree planting which would direct the eye by masking the superfluous and emphasizing the dramatic in an otherwise too sprawling view.)

3. It will not result in a blanket effect in the distant view and thereby muffle the clean sweeping lines of the hills. (On the other hand, some existing outlines in distant views are blurred at present by lack of contrast. There may be situations where forested areas might be employed to improve views by emphasizing outlines, by creating new landmarks, or by dramatizing a scene in which repetition of form, texture, and colour threaten to become monotonous.)

4. It will not lessen the feelings of spaciousness or loneliness where these are extraordinarily impressive and highly valued.

5. It will not contradict the grain of the land upon which it is sited, but will follow the sweep of the contours in its outline.

6. It will not obliterate subtle modelling or the interests of water in the combes. (But by planting on one side only and leaving a waterside verge, the dramatic

effect of many combes could be heightened. There are also combes of no particular merit which, if planted, could be transformed into quite significant landscape features.)

7. It will not interfere unreasonably with good agricultural land. (But the integration of forestry and agriculture should be closely studied for there must be considerable areas of land on farms where afforestation would benefit the agricultural economy by providing shelter at least.)

8. It will not interfere with areas of scientific importance, archaeological or other ancient monuments, recreational activities or water catchment, but will be integrated with these interests.

9. It will not, by reason of its ancillary works, such as access roads, be detrimental to the landscape.

10. It will not prove to be unplantable for any technical reasons or unmanageable by reason of considerable isolation from other forest areas.

These are the broad primary principles upon which more than fifty areas ranging approximately from 10 to 200 acres in extent and totalling about 4,000 acres, were selected as potential forest land. Beyond these measures, which are relatively clear cut, there are other less tangible judgements which were employed in site selection. A sense of balance between woodland and moor and a feeling for the varying qualities of the scenery are, for instance, perceptions difficult to describe or justify shortly. But it is my belief that an aesthetic code can be employed in forest design and that it is important to use such discernments, in conjunction with the primary principles, if afforestation is to be introduced into the landscape of a National Park in a subtle manner which will enhance rather than disrupt each scene.

Taking all interests into account, the East Central Belt appeared to provide the most promising ground for new afforestation in the Exmoor National Park, followed by the South-West Fringe and the Brendons. Suitable sites were less evident in Exmoor Forest and the Coastal Strip.

The design of each proposed new woodland had then to be considered and, again, a number of fairly clear-cut requirements in the interests of amenity at once emerged. Thus:

1. *Size.* Some State plantations are out of scale with the surrounding countryside. Smaller plantations, grouped in localities to facilitate management, appear to be more easily absorbed in most landscape patterns in the Exmoor Park at least. Bare land between plantations might be employed to provide firebreaks and access routes for farmers and visitors.

2. *Shape and layout.* Not only the outlines but the rides within each plantation must be shaped to follow the contours of the land. Perimeter fencing may still be laid out geometrically to reduce expense because it is usually scarcely noticeable in the landscape. Pieces of ground left between fence and plantation may then be planted casually with a few trees to give the fringes of the woodland a more natural appearance.

3. *Crop arrangements.* Pure hardwood crops can be readily accepted as they will be known to repeat the traditional patterns of colour and texture. However, they

can be surprisingly monotonous, sometimes, and the value of local topography in the relief of monotony should be noted.

Pure conifer crops, introducing a new colour and form into the scenery, can provide seriously jarring effects. But they also have special values sometimes in emphasizing land form or in giving a dramatic interest. Harsh dividing lines between crops are undesirable. Mixtures of conifers may generally present a more interesting appearance than pure crops, but any regularity of pattern must almost always be avoided, particularly on hillsides.

Hardwoods and conifers in intimate mixture are widely acceptable because they offer a greater variety of effect. The use of even quite uneconomic hardwoods in mixture with conifers must be seriously considered if the visual effect of the plantation can thus be enhanced at any stage in its formation. Similarly, the retention of uneconomic hedges, hedge trees, or other perimeter timber must be considered.

There are also cases where the retention of whole woods of a totally uneconomic type such as the coppice oak in Horner Water has to be recognized because of their overwhelmingly high value in landscape.

You will no doubt have noticed that many of these notes of mine upon the design of individual woods repeat the observations which some of you made in the Lake District in 1955. You were learning lessons then from existing plantations. I have done much the same thing in Exmoor except that I have tried to approach the problems of forestry and amenity primarily from the landscapist's point of view and to take other interests into account.

The need for compromise which has been mentioned earlier in this paper is clear in many ways. Forest management in the form suggested of small separated blocks, not as easily accessible as might perhaps be wished, or of irregular shape and sometimes composed of complex mixtures, is unlikely to be cheap. But I would ask those concerned with forestry to accept the additional cost and difficulties in the interests of national amenity. At the same time, however, I would also ask those concerned with amenity to remember that landscape is not a static thing, but has constantly evolved through the centuries in response to both natural influences and the needs of man and that it must continue to do so.

We are witnessing the early and sometimes ungainly stages of a woodland renaissance in this country which employs new materials and patterns in our landscapes. If the forester's skill is used imaginatively, there are great opportunities to enrich the beauty of our countryside with new woods. Co-operation and understanding are needed between all concerned. While my scheme may possess many weaknesses in its present early form, my ideas are advanced as a sincere attempt to search for a new means of co-operation upon controversial and difficult matters. It seems that my plan may have some merit in Exmoor so perhaps the principles may be applicable elsewhere.

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FIG. 1. Conifers well sited on intermediate slopes, diversified with rough land, but species divisions arranged harshly.

FIG. 2. Afforestation with conifers on the valley side could enhance this scene.

FIG. 3. The upper fringes of new hillside plantations should be designed with the natural effect of old woods such as this one in mind.

PLATE III

PROBLEMS OF YIELD CONTROL AND INVENTORY IN BRITISH FORESTRY

By D. R. JOHNSTON

(*Forestry Commission*)

SUMMARY

Part I. The greater part of the output from British forests during the next few years will come from thinnings. Final fellings will come predominantly from overmature crops which are a legacy from the past or from unsatisfactory crops. Yields from thinning and felling must therefore be considered quite separately. Thinning yields will depend upon increment but yields from final felling will depend mainly upon the area of overmature crops to be removed within a predetermined period of years. The data required for thinning and felling control are discussed.

Part II. The theory of sampling in relation to forest enumeration is discussed briefly. The standing volume of a forest may be estimated in three ways; by the application of yield tables; by visual estimation; or by measurement. The last method may mean measuring all the trees or only a sample and the theory of enumeration plot procedure is discussed. Increment may be estimated by comparing successive enumerations of the standing crop; from yield tables; or from measurements within the tree. Finally the choice of enumeration method is discussed.

INTRODUCTION

MANY foresters in Britain are beginning to have to deal for the first time with questions of yield control and forest inventory. Because such problems are new to us we can as yet offer no authoritative solutions and this paper is intended rather to draw attention to some of the problems and to suggest solutions which have, to some extent, been tested in the field. The paper is divided into two parts; Part I: Problems of Yield Control, and Part II: Methods of Estimating Standing Volume and Increment.

The two topics need to be discussed separately because the first is concerned with fundamental problems of planning and management while the second deals with the mechanics of data collection. Each, however, has a bearing upon the other; one cannot control the yield unless one has some idea of what it should be, and it would be a waste of time collecting data on growth and yield unless one knew what to do with them.

Part I. Problems of Yield Control

1. *The relationship between growing stock and cut*

Forestry differs from most other industrial undertakings in that the greater part of the production plant is visually indistinguishable from its products. The chicken in fact is indistinguishable from the egg. It is relatively easy to arrive at an estimate of increment but more difficult to apportion the increment between growing stock and cut, and the cut in its turn between thinning and felling. It must be regarded as axiomatic in State forestry that an approximation to sustained yield

is desirable and perhaps ultimately essential either for individual working-plan areas or for groups of separate areas serving a common market.

2. *The relationship between thinning and final felling*

In even-aged forests the volume removed in thinnings must be considered quite separately from that removed in final fellings. Thinning is a silvicultural and economic operation which determines or is perhaps determined by the type of product to be grown, while clear-fellings, as well as harvesting the final crop at an age or size dictated by silvicultural and economic considerations, also determines the age-class structure of the forest. If, considering the forest as a whole, an error is made in forecasting the volume to be obtained from final fellings, it can only be corrected by a corresponding adjustment to the thinning production over a short period and only at the expense of the ideal thinning régime. Over a long period, adjustments either to thinning production in order to balance errors in felling forecasts or to felling production in order to balance errors in thinning forecasts are likely to aggravate the abnormality in age-class distribution or to reduce the productive capacity of the forest and the quality of the timber.

3. *The relationship between increment and final felling*

Control of final fellings may be by area or volume or both. If a forest approaches normality in its age-class distribution the yield from final fellings will normally be closely related to increment. Ideally in fact the combined yield from thinnings and final fellings will equal the increment. In Britain, however, our forests are generally so abnormal in their age-class structure that at the present time final fellings bear little relation to increment. In deciding the extent of such fellings we are guided rather by the following considerations:

(i) The length of time that the mature or overmature stands may be expected to remain reasonably vigorous.
(ii) The ability of markets to absorb the produce.
(iii) The necessity to fulfil contracts.
(iv) The amount of replanting that our resources allow us to undertake.
(v) The amount of subsequent weeding, cleaning, &c., that can be undertaken.
(vi) The amount of clear felling that can be tolerated on protective or amenity grounds.
(vii) The economic consequence of felling stands before or after the rotation which is considered, for various reasons, to be optimum.

In Britain today these factors completely over-ride any immediate considerations of sustained yield or of yield control related to increment. Provided the prescribed final cut is logical and realistic in the light of the considerations mentioned above we need only ensure that it will improve the age-class distribution in the future; we need not aim at theoretical perfection. Nevertheless the time is approaching when we shall have to take some deliberate steps to improve the age-class structure of the large areas of forest planted in the 1920's and 1930's; a good example being Thetford. Of a total area of 43,000 acres, 35,000 acres were planted

between 1925 and 1939. Since the area is completely planted and new acquisitions are unlikely, felling and replanting is the only method of widening the age range, although the size-class structure may be influenced by varying the intensity of thinning. The criteria governing felling prescriptions are somewhat different here from the case of overmature hardwoods discussed above. There may be no immediate urgency to fell on silvicultural or short-term economic grounds although there may well be crops which could with advantage be replaced with species better adapted to the site, better suited to local markets, or more resistant to disease associated with the region. Fundamentally, however, the object of felling will be to improve the age-class structure although the opportunity will be taken to replace some, at least, of the less satisfactory stands at an early stage. Even when the techniques of introducing second rotation crops are fully developed the effects of proposed fellings on labour requirements and markets are likely to be limiting factors and will tend to dominate any plans to achieve normality within a given period.

Therefore neither the achievement of normality nor the balancing of out-turn with increment can be over-riding considerations in our policy. In the present stage of development of forest management yield control must be largely by area although the extent of the areas prescribed for felling will often be determined to a large extent by the volume which it is estimated will result from them. These estimates of volume may also have to serve as a basis for long-term contracts of sales and on occasions, when the fulfilment of a contract is of over-riding importance, the cut may be prescribed in terms of volume rather than area. But when cut is unrelated to increment this may be described as a method of exploitation control rather than yield control. It is only when an approximation to normality has been attained that it becomes desirable or practicable to relate the final cut to increment and to prescribe the cut in terms of volume rather than area.

4. *Thinning control*

Although in even-aged forests thinnings are usually cut on an area basis, the long-term control of thinnings must ultimately be by volume, otherwise there is no assurance that too large or too small a proportion of the increment is not being harvested. Within the range which is silviculturally possible a thinning grade is determined very largely by economic considerations, but when a thinning grade has been prescribed there are two ways in which it may run into difficulties. The crop may grow slower or faster than anticipated so that, even if the prescribed or forecast out-turn is obtained, the intensity of the thinning may be greater or less than intended and the main crop consequently over- or under-thinned according to the intentions for that particular forest. On the other hand the prescribed thinning intensity may prove to be theoretically correct but owing to inaccurate marking the amount actually cut may differ from that prescribed or forecast. Either or both of these mistakes may confuse the regulation of the thinning yield and introduce difficulties into management and marketing. It is only by making periodic estimates of growing stock and increment and by keeping careful records of past production that reasonably reliable forecasts of future thinning production became possible.

There is, however, a fundamental difference between long-term thinning forecasts and thinning control and short-term forecasts and control. The long-term forecast is based upon increment and involves forecasting future increment and allocating this between thinning production and accretion to the growing stock. For any given stand the proportion of the increment to be removed in thinnings depends upon the specific composition, age, quality class, and thinning intensity, while for the forest it depends in addition upon the age-class structure as a whole. Thus in a young, more or less single-aged forest 60 per cent. or more of the increment might be left uncut to increase the growing stock while 40 per cent. would be removed in thinnings. As the forest ages the proportions tend to be reversed. For example, according to the Forestry Commission yield tables about 25 per cent. of the increment of Norway spruce (*Picea abies* Karst), having a top height of 30–40 feet, is removed in thinnings, while this percentage has increased to 57 per cent. in stands having a top height of more than 70 feet. The short-term thinning forecast and control on the other hand is concerned not so much with increment alone but takes into account also the current condition of the growing stock. If the forest has been overthinned, production in the immediate future may be very low whereas if the stands are underthinned the short-term production may legitimately be considerably greater than a theoretical figure based upon increment.

5. *Data required for yield control*

If we accept the fact that yield control in British forests is likely to be largely by area for at least the next few decades, we need to examine the reasons for measuring the growing stock and increment of our forests.

On the national scale a knowledge of the growing stock of the country is essential because the forests, as well as being a source of production, constitute also reserves of timber which may be drawn upon when for one reason or another the normal volume of imports is unavailable or unduly expensive. This information may however be obtained from a very small sample which would yield practically no information about individual forests.

On the forest scale, felling prescriptions by area cannot be made without a knowledge of the volumes which will result from the operations. This information will be required in forecasting labour and machinery requirements and in planning exploitation and sales. The volume estimates will normally be required by species or species groups and by size classes. It is doubtful if great precision is normally required in State forests since it is usually possible to deal with modest fluctuations in output by varying the proportion of timber sold standing or by making adjustments between forests in order to satisfy markets and contracts.

If one considers the extreme case of a young conifer forest in which the range of age classes is narrow and in which no final fellings are proposed for at least 10 years, it is doubtful if a knowledge of the standing volume is necessary for immediate management. In such a forest, however, one of the questions which must be answered when a working plan is prepared is whether steps should be taken to improve the size or age-class structure. In order to answer such a question

intelligently some knowledge of standing volume and size-class distribution by species and sites is essential.

In most of our forests the production from thinnings is at present more important than the production from fellings. In the younger forests in particular, an estimate of the current and future volume increment by species and size classes is of more immediate importance than a knowledge of the standing volume itself. Having made an estimate of the future increment, it must be allocated between thinning production and accretion to the growing stock and a thinning régime put into operation which allows an adequate build-up of growing stock. Forecasts of increment may turn out to be inaccurate and in any case when a species is growing on a site for the first time or if no adequate records are available, the proportion of increment to be allocated to thinning production must be somewhat arbitrarily determined—probably from yield tables. Periodic enumerations of the growing stock enable the forest manager to check the accuracy of earlier forecasts, to keep a watch on the development of the forest and to guide it towards maturity and normality.

Part II. Methods of Estimating Standing Volume and Increment

6. *Introduction*

Before discussing methods, it is necessary to be quite clear about three statistical terms.

Standard deviation (S.D.). This is a measure of variability and takes account of the distribution of values about their mean; for example, the means of 1, 5, and 9 and of 4, 5, and 6 are both 5 but the former series has the greater standard deviation. The standard deviation of a series of values is obtained by squaring all the differences from the mean, totalling them, dividing by one less than the number of values, and taking the square root of the result. For example,

(1) *Values*	(2) *Mean*	(3) *Differences from mean*	(4) *Differences squared*
2	..	−3	9
3	..	−2	4
4	..	−1	1
5	5	..	..
6	..	1	1
7	..	2	4
8	..	3	9
			Total 28/6 = 4·66

S.D. = $\sqrt{4{\cdot}66} = \pm 2{\cdot}16$ or, expressed as a percentage of the mean.

$$= \frac{2{\cdot}16}{5} \times 100 = \pm 43{\cdot}2 \text{ per cent.}$$

Normally in sampling for forest inventories the values (column (1) above) are the volumes per acre of $\frac{1}{10}$-acre sample plots and the true standard deviation of a

crop could be obtained by dividing up the whole crop into $\frac{1}{10}$-acre plots, measuring the volume standing on each and performing the calculations described above inserting the plot volumes in column (1). This could not be put into practice, but an approximate estimate of the standard deviation may be calculated from the volume per acre of a limited number of samples.

Standard error (S.E.). This is a measure of the *precision* of an estimate and in forest inventories is sometimes expressed as a percentage of the mean. For example, an estimate of volume might be expressed as 100,000 h. ft. $\pm$ 10 per cent., meaning that the volume in fact lies between 90,000 and 110,000 h. ft. The standard error is obtained by dividing the standard deviation by the square root of the number of samples (plots). For example, if a crop is estimated to have a standing volume of 50,000 h. ft. and a S.D. of $\pm$30 per cent. and the estimate of volume has been obtained from 25 plots, the standard error would be $30/\sqrt{25} = \pm 6$ per cent. or 3,000 h. ft. and the result could be expressed as 50,000 h. ft. $\pm$ 3,000 h. ft. (or $\pm$6 per cent.).

Confidence limits. The S.E. of $\pm$6 per cent. quoted above means that there is a two-to-one chance that the estimate of volume is correct to within $\pm$6 per cent. Such a small chance would not give anyone much confidence in the estimate. In order to increase confidence, therefore, the normal statistical convention is adopted of expressing the precision as a nineteen-to-one chance (the 95 per cent. confidence limit). In order to do this, the standard error has approximately to be doubled, so that in the example quoted above, the standard error would be expressed as $\pm$12 per cent. There is thus a two-to-one chance that the true volume lies between 47,000 and 53,000 h. ft. but a nineteen-to-one chance that it lies between 44,000 and 56,000 h. ft.

7. *Sampling*

Both standing volume and increment may be measured by complete enumerations or by sampling. A 100 per cent. enumeration is rarely, if ever, a practicable or necessary proposition in Britain. It is a question, therefore, of choosing the most efficient form of sampling of which there are two principal alternatives—systematic or random. Systematic sampling ensures an even distribution of plots throughout the population to be sampled but suffers from the disadvantage that, unless assumptions which may be unjustified are made, it does not allow the precision of the result to be calculated. With random sampling on the other hand the precision of the result may be calculated and the disadvantage of irregular distribution of plots may be largely overcome by subdividing (stratifying) the population (e.g. forest) into a number of subdivisions (or strata), such as species or age classes, so that each stratum is represented by a certain number of plots. As well as ensuring an equitable distribution of plots, stratification leads to economy in sampling. Some strata, having less variability than others, may be sampled with fewer plots whereas if the forest were sampled as one unit some species would have more plots than necessary while others might have too few. The precision of an estimate depends almost entirely upon the number of enumeration plots and the variability (standard deviation) of the crop being sampled and is almost independent of the

acreage being sampled,[1] since the standard deviation divided by the square root of the number of samples (plots) gives the standard error. For example, in a uniform crop of 5,000 acres twenty-five plots might be sufficient to give an estimate to within plus or minus 10 per cent., whereas in a more variable crop of 1,000 acres fifty plots might be required to achieve the same percentage precision. Obviously however, in any given crop type there is a tendency for a large area to have a greater variability than a smaller one.

On the other hand, for the purposes of forest management, the absolute error of the estimate is generally of more importance than the relative error. Thus a 10 per cent. error in 10,000 h. ft. amounts to 1,000 h. ft. which may be worth £100 or take one man two weeks to fell whereas a 10 per cent. error in 1,000,000 h. ft. amounts to one hundred times as much.

It is therefore often necessary to put more plots into an important stratum, partly to reduce the absolute error of the stratum estimate and partly to supply more detailed information about the stratum, such as volumes by age classes. From a practical point of view there is therefore much to be said in favour of a fixed sampling percent. in all strata. If the area is large, there will be more plots giving a greater percentage precision and therefore tending to reduce the greater absolute error. The table below demonstrates the effect of sampling at the rate of one enumeration plot per 30 acres in crops having a standard deviation of ±30 per cent. assuming a standing volume of 1,000 h. ft. per acre.

Area of stratum (acres)	*No. of plots per stratum*	*Precision %**	*Absolute precision per stratum (b. ft.)**
10,000	333	± 3·3	±330,000
5,000	166	± 4·7	±235,000
2,000	66	± 7·5	±150,000
1,000	33	±10	±100,000
500	17	±15	± 75,000
250	8	±21	± 52,500

* At 95 per cent. probability limit.

The following points should be noted.

(i) The precision percent. is obtained by dividing the assumed standard deviation of the crop (±30 per cent.) by the square root of the number of plots (to give the standard error) and multiplying by two to increase the probability from two to one to approximately nineteen to one.

(ii) A constant sampling intensity will not result in a constant absolute precision. Thus one plot in 30 acres over 1,000 acres results in an absolute precision

[1] The sampling fraction only begins to be important when it exceeds 20 per cent. For practical purposes it may be considered to have no effect upon the precision of the estimate under our conditions. The mathematical expression is as follows:

$$\text{True precision} = \text{estimated precision} \times \sqrt{\left(1 - \frac{\text{sampling percent.}}{100}\right)}.$$

Therefore if the sampling percent. is less than 20 per cent. the expression inside the square root sign is more than 0·9.

of ±100,000 h. ft. while over 5,000 acres the absolute precision is ±235,000 h. ft. although the percentage precision has improved from ±10 per cent. to ±4·7 per cent. It would not be practicable to obtain the same absolute precision over areas differing greatly in size since this would mean either a very large number of plots in large areas or a percentage precision in the small areas so poor as to be valueless. For example, if it was desired to obtain an absolute precision on the 5,000 acres of ±75,000 h. ft. (i.e. the same as on the 500 acres) 1,600 plots would be necessary while an absolute precision on the 500 acres of ±235,000 h. ft. would be equivalent to a percentage precision of ±47 per cent. Some compromise is therefore necessary and, although particular circumstances will necessitate special sampling programmes, a constant sampling intensity of one plot in thirty acres may be regarded as a reasonable compromise between constant percentage precision and constant absolute precision, provided that special steps are taken with very large or very small strata.

The small, heterogeneous forest areas which commonly occur in parts of Britain present a special sampling problem. The area occupied by each species may be so small that a very high sampling intensity would be required to obtain reasonably precise estimates of volume for each species. In such a case it may be preferable to rely upon visual estimates of volume for each species (made individually for each stand) but to check the total of these visual estimates by a sample survey of the forest as a whole. Methods of sampling and calculation are available which produce a reliable estimate of the total volume of the forest using a relatively small number of plots but these results are quite unreliable when applied to any individual stratum. They may give a valuable check upon the sum total of all the visual estimates but no check upon the estimates of any one stratum (e.g. species or age class).

Another problem is the enumeration of a species represented by a wide range of age classes. As mentioned above, the precision of an enumeration depends upon two things—the standard deviation of the volumes per sample plot and the number of plots measured.

If we reduce the estimated standard deviation by additional stratification into, for example, age classes, we may obtain a number of sub-strata each having a smaller standard deviation than the species as a whole but each occupying a smaller area of ground and therefore justifying the use of a smaller number of sample plots. We are therefore increasing the efficiency of the enumeration by reducing the standard deviations but to some extent off-setting this improvement by reducing the numbers of the plots per stratum, thus increasing the standard error.

For example, 100 acres of Sitka spruce (*Picea sitchensis* Carr.) ranging in age from 30 to 60 years, may have a standard deviation (of volumes per $\frac{1}{10}$-acre plot) of ±60 per cent. In order to achieve a precision of ±10 per cent. in an estimate of volume, about 136 plots would be required. If the Sitka spruce were stratified into three age groups each occupying about 33 acres and each having a standard deviation of ±30 per cent. a total of 38 plots would be needed in each sub-stratum to achieve the same precision. There has been some gain in economy since 114 plots instead of 136 have been needed. A very much greater gain in economy would,

however, be possible if the apparent standard deviation of the species as a whole could be reduced without further stratification since a much smaller number of plots could be used to cover the whole area.

Where a standard deviation depends in part upon a continuously changing variable such as age, or possibly altitude, it is possible to eliminate the effect of this variable when calculating the standard deviation by plotting plot volume against plot age and making an allowance for the greater volumes naturally associated with older crops.

The effect of this is to eliminate that part of the variability due to high plot volumes in the older plots and low plot volumes in the younger plots. The calculated standard deviation therefore depends solely upon the variability within any given age class. Since the whole species is now regarded as one stratum all the plots in the species are taken into account when calculating the standard error from the formula:

$$\text{standard error} = \frac{\text{standard deviation}}{\sqrt{\text{total no. of plots}}}.$$

8. *Methods of estimating the growing stock*

(*a*) *General.* There are, fundamentally, three methods of estimating the growing stock of a forest. The first method consists in applying yield table data to the various species in the forest, making due allowance for unproductive areas and for variations in stocking; the second is to estimate visually the volume of each stand or sub-compartment, and the third is to measure the trees either by a complete enumeration or by sampling. The first two of these methods depend upon knowing the distribution by area of the various crop types for which separate estimates are required. This preliminary mapping may be carried out by ground or air survey alone or in combination.

(*b*) *Yield tables.* Yield tables summarize the data obtained from a number (usually a large number) of fully stocked sample plots which have been thinned in a particular way and which are situated over a relatively large area, such as a state or a country. In this country they are available only for pure crops and for a single thinning régime although in some countries, e.g. Germany, they have been published for well defined and important mixtures, such as beech (*Fagus*) and silver fir (*Abies*) and for more than one thinning régime. The British yield tables are based upon top height, so that if the area distribution of species within a forest by top height (or by age and quality class) is known, an estimate of standing volume may be read directly from the yield table. Such a method is liable to very considerable inaccuracies, however. Yield tables refer to fully stocked areas while the forest will include an unproductive area of roads, rides, ponds, windblown gaps, checked areas, &c. Furthermore, owing to the variations in site, treatment and genetical properties of the individual stands, the development of particular stands or forests may differ greatly from the yield table pattern. The thinning régime adopted in a particular forest may differ considerably from that assumed in the yield table, or a species may follow the yield table pattern in one respect, e.g. height growth for a given age but not in others, e.g. basal area per

acre or form factor. The first of these difficulties, namely the presence of unproductive land within the compartment areas and the difference in stocking between forest crops and yield table sample plots may be largely overcome by working out a suitable conversion factor for the forest. But the second and more important limitation of yield tables, namely the difference in treatment and growth pattern between individual crops and those represented by the yield table data, renders them unsuitable as a means of obtaining reliable estimates of standing volume. Careful local records over a period of time may, however, be regarded as a form of local yield table. These may give more reliable estimates of volume, particularly if they have been kept for a whole rotation and are applied to a succeeding rotation of the same species on the same site. They can even be applied to somewhat younger, contemporaneous crops growing on a similar site in the same locality and treated in the same way as the crops for which records are available.

(*c*) *Visual estimates.* An estimate of the volume of a forest or of any species or crop type within a forest may be obtained by adding together the visual estimates of volume of each stand or sub-compartment. The accuracy of the result depends, to a greater extent than in any other method, upon the skill and experience of the surveyor and it is not possible to define precisely how the estimates should be made, since different individuals have different ideas. Some people work almost instinctively, while others perform conscious mental calculations, estimating, for example, the basal area, mean height, and form factor or assessing the volume of the mean tree and the number of stems per acre. The surveyor may use a relascope to assist in his estimates of basal area or occasionally measure an enumeration plot in order to check his standards. If careful relascope sweeps or rough enumeration plots are used in every stand the method becomes a form of haphazard sampling and has little to commend it. But if the mechanical aids are kept to a minimum it is an extremely economical way of obtaining an estimate of volume provided each stand has to be visited in any case in the course of, for example, working plan crop assessment surveys.[1] The disadvantages are considerable, however. Since the result depends to such an extent upon the personal skill of the surveyor, only experienced men can be employed in the work. There is little check on the accuracy of the result, although it is the practice in some countries, particularly in Scandinavia, to calculate conversion factors for individual surveyors and to adjust all their estimates accordingly.

It is possible to check the total estimate for the whole forest by an economical form of stratified random sampling, as described in section 7 above, but not practicable to check the result for any one species. Thus the random sample might confirm the total of visual estimates although oak (*Quercus*), for example, might have been grossly overestimated and spruce (*Picea*) grossly underestimated. It is, however, the only practicable way of obtaining inexpensive estimates of volume for units as small as compartments or sub-compartments.

[1] Crop assessment: the recording of crop type, age, specific composition, quality class, and stocking by sub-compartments.

(*d*) *By measurement.* The principal difference between methods of measurement is the intensity of sampling, which may range from 100 per cent. to a fraction of 1 per cent. This has been discussed in section 7 above. The other variations are plot size and shape, and the mechanics of measuring. Because the precision of the result depends so largely upon the number of plots rather than upon the sampling percent., the tendency is to make plots as small as possible. There has been little systematic investigation of this problem in this country but there is some evidence that the $\frac{1}{10}$-acre enumeration plot is unnecessarily large for fully stocked pole-stage conifers and rather too small for crops of widely spaced trees such as mature oak. Although a smaller plot is statistically and economically advantageous it requires more careful measuring, since the effect of a peripheral marginal tree, included or excluded in error, becomes correspondingly more important. Plot shape is largely a matter of practical convenience although the smaller the plot the more important it becomes to reduce the circumference/area ratio. This is best achieved with a circular plot. Whatever the method of sampling and the type of plot, three factors of volume have to be measured, namely basal area, height, and form factor.

An error of x per cent. in the measurement of basal area, height, or form factor will affect the result equally but because the girth has to be squared in order to arrive at the basal area, an error in girth will be twice as important as an error in height or form factor. Girth is easier to measure than height or form factor and is therefore more likely to be measured accurately, but on the other hand girths are generally two to three times more variable than heights in an even-aged crop.

These considerations are summarized below:

	Girth	*Height*	*Form factor*
Ease of measurement . .	Easy	Difficult	Very difficult
Accuracy of measurement .	Good	Less accurate	Less accurate
Variability	Very variable	Less variable	Less variable
Mathematical effect on value .	2	1	1

The theoretically ideal procedure would be to measure the volume of each individual tree in the sample plot, either by felling it or by climbing and measuring it in lengths. This would be quite impracticable, but because height and form factor vary with girth and because volumes are required by girth classes, average values for height and form factor are assumed for each girth class. In order to obtain estimates of height, the heights of a proportion of the trees in the plot are measured and the form factor of these measured trees is estimated from form factor tables (volume tables). Knowing the form factor, height, and girth of a proportion of the trees in the plot, it is possible to obtain an average form height for each girth class via the tariff tables. The appropriate form height value (tariff number) is then used to obtain the total volume of the plot by girth classes.

Basal area may be measured with a relascope, thus saving the time spent in laying out an enumeration plot, but it can only give information about the size-class distribution if a relatively elaborate procedure is adopted and it is doubtful

if a relascope sweep can ever be as precise as a sample plot measurement. The relascope also presents a particular problem when used in random sampling if the plot centre falls near the boundary of a stratum. There is no easy way of knowing if the relascope sweep is extending beyond the boundary of the stratum and thereby increasing the sampled area by an unknown amount.

9. *Methods of determining increment*

(*a*) *General.* There are basically three ways of estimating increment; these are (i) by comparing successive enumerations of the standing crop taking into account the volume removed in the intervening period, (ii) from yield tables, (iii) from measurements within the tree.

In abnormal forests, where the average age of the forest is increasing with time, methods (i) and (iii) which give retrospective estimates leave the difficulty of forecasting future increment largely unsolved, while method (ii) which gives an estimate of increment at the time of survey, provides some basis for forecasting future increment if one assumes that the crop under investigation is going to follow the yield table pattern of growth.

(*b*) *The comparison of successive enumerations.* This method presupposes that the two figures to be compared are in fact comparable. With the passage of time, however, the specific composition of a forest may change due to recruitment, felling, and new plantings, and in particular old hardwoods may be felled and replaced with young conifers. It is obvious, therefore, that a comparison of the total results of successive total enumerations will give little information about the actual performance of the various species comprising the growing stock and will form a very poor basis for forecasting future increment.

If, however, the forest is first stratified, the periodic enumerations may be restricted to those strata which are likely to retain their identity for at least several decades.

The initial stratification is a matter of some importance. Since one of the primary objects of successive enumerations is to provide statistics for estimating future production, it might perhaps seem logical to stratify the forest into species and each species into age and quality classes. But quality classes are transient. During its life a crop may pass through several quality classes, and if, in the future, the specific composition of a sub-compartment is changed, the quality class of the new species may bear little relation to that of the previous crop. By its very nature the method of periodic inventory may take several decades to produce results. Stratification for periodic inventory should therefore be based upon something more permanent than quality class. The only relatively unchanging factor is soil or site.

A reliable soil or site map is therefore a prerequisite to the introduction of the method of periodic inventory in heterogeneous abnormal forests. Production data may then be accumulated over the years for each species on each site in the form of a local yield table. As the specific composition of the forest becomes adjusted to site as a result of increasing knowledge of site/species relationships, so the proportion of the forest covered by periodic enumeration will increase.

Each enumeration must be relatively accurate if reliable estimates of increment are to be obtained within 20 to 30 years. If each enumeration is accurate to within ±10 per cent. and the successive enumerations are 10 years apart the total error may be as much as ±20 per cent. which is 2 per cent. per annum or perhaps 50 per cent. of the increment assumed at about 4 per cent. per annum.

A 100 per cent. enumeration is hardly a practicable proposition in Britain. It is therefore a question of choosing the most efficient form of sampling taking into account the fact that the enumeration will normally be intended to provide estimates of standing volume as well as of increment.

The accuracy of the estimate will depend more upon the number of plots in each stratum than upon the sampling intensity. In order to keep the sampling percent. at an economic level, therefore, the individual plots must be small—of the order of $\frac{1}{10}$ acre. The best estimates of standing volume are obtained by putting in a completely new series of random plots at each re-enumeration whereas the best estimate of increment is obtained if the plots are permanent, the same plots being measured at each re-enumeration.

In either case the distribution of plots between crop types must be adjusted to the changing area of each crop type due to fellings and planting. Whether permanent or temporary plots are employed, a true comparison between successive volume estimates is only possible if each enumeration is carried out in the same way using, for example, the same volume or tariff tables each time. These two methods are fundamentally different, because with temporary plots the estimates of volume removed between enumerations are obtained from routine forest records for the whole forest area whereas with permanent plots records of volume removed are kept separately for each plot. A modification of the method of permanent sample plots is to abandon a proportion at each re-enumeration and to select randomly an equivalent number of new ones in order to effect a compromise between the most efficient methods of estimating standing volume and of increment respectively.

A serious disadvantage of any method involving small permanent plots is the practical difficulty of maintaining their identity over a long period and of recording the volume removed from them. There is also some difficulty in ensuring that they do not receive special treatment. These difficulties are so considerable that it is doubtful if the use of permanent enumeration plots can be regarded as a practical method of measuring increment. They should not, however, be confused with indicator sub-compartments which serve a different function in providing some form of silvicultural control.

(*c*) *From yield tables.* Yield tables may be used alone or in conjunction with a standing volume enumeration to obtain estimates of current and future increment. They can only be used, however, if the forest has first been stratified by species and quality (or top height/age) classes. If they are used alone or in conjunction with a visual survey of standing volume, the specific composition, top height, and area of each stand must be known. The increment per acre is then read directly from the yield table and applied to the area of the stand. The unit of measurement will usually be the sub-compartment which may include several quality

classes, the areas of which will not be known exactly. The surveyor must therefore estimate also a mean quality class or the approximate area occupied by each quality class. If the basal area can be estimated visually or by relascope, the method can be made very much more precise, and for this reason yield tables are more efficient for estimating increment if used in conjunction with volume enumeration plots. The careful measurement of such plots produces a reliable figure for basal area and quality class. If the basal area of the enumeration plot is known, it can be compared with the yield table basal area and the yield table value for increment adjusted accordingly. It is known that for any given stand, basal area can vary quite considerably with very little effect upon increment. In fact the reduction in increment is likely to be negligible if the basal area stocking is 80 per cent. or more of the yield table basal area. On the other hand, if the basal area is greater than that given in the yield table the increment will not exceed the yield table figure. Various arbitrary and empirical methods may be adopted for adjusting the yield table increment figure. One which has been found convenient is to multiply the yield table increment by the sine of the percentage ratio of plot basal area to yield table basal area if this percentage is less than 90. This method involves no reduction in yield table increment if the plot basal area amounts to 90 per cent. or more of the yield table basal area since sine 90 = 1, but it makes an accelerating reduction in increment as the plot/yield table basal area ratio diminishes. This accords with field observation.

The application of yield tables to mixtures is somewhat complicated because the basal area of each constituent of the mixture has to be considered separately, although the total stocking of the plot influences the increment rate of each constituent. There are no established criteria for assessing the degree of stocking implied by total basal areas of mixtures, and indeed it is difficult to see how this could be put upon a practicable mathematical basis considering the endless possible complications resulting from species each having different basal areas when fully stocked, mixed in various proportions. The only practicable way of estimating the stocking of a mixture is to make a purely subjective estimate, taking into account canopy stocking, basal area, number of stems per acre, and full yield table stocking of each constituent. If a direct arithmetical proportion of the yield table increment is allocated to each constituent on the basis of the ratio crop-stocking/yield table-stocking, the result will be an underestimate, since increment does not fall off in direct proportion to basal areas. The directly proportional estimate of increment must therefore be multiplied by the factor $\frac{100 \sin x}{x}$ (where x is the subjectively assessed stocking percentage) to correct this underestimate. For example let us consider a mixture of Scots pine (*Pinus sylvestris* L.) and Douglas fir (*Pseudotsuga taxifolia* Brit.) aged 30 years, quality class II, and estimated visually to be 60 per cent. stocked.

Scots pine

Yield table basal area = 93 h. sq. ft./acre; yield table C.A.I. = 158 h. ft./acre/annum.
Actual basal area = 26 h. sq. ft./acre.

$\therefore$ directly proportional C.A.I. $= 158 \times \frac{26}{93} = 45$ h. ft./acre/annum.

Corrected C.A.I. $= 45 \times \frac{100 \sin 60}{60} = 65$ h. ft./acre/annum.

Douglas fir

Yield basal area = 120 h. sq. ft./acre; yield table C.A.I. = 278 h. ft./acre/annum.
Actual basal area = 59 h. sq. ft./acre.

$\therefore$ directly proportional C.A.I. $= 278 \times \frac{59}{120} = 136$ h. ft./acre/annum.

Corrected C.A.I. $= 136 \times \frac{100 \sin 60}{60} = 196$ h. ft./acre/annum.

All the figures in a yield table are based on top height. There may therefore be a discrepancy between a yield table value for increment and the true value in a particular crop which happens to be accelerating or decelerating in growth. For example, after some years in check, a stand may begin to grow very rapidly, but because quality class depends upon the top height attained in the whole period since planting, the yield table may give an underestimate of the current annual increment of the stand. This applies particularly to plantations less than about 25 years old, which have been in check for more than about 10 years. For such stands more reliable estimates of increment may be obtained from Table I derived from the basic Forestry Commission yield table data. This table is taken from a paper by A. M. Mackenzie and J. M. Christie (1958).

TABLE I

Volume increment per acre for every one foot of height growth by height classes and species

	Volume increment per acre in hoppus feet over bark for every one foot of height growth (from the Revised Yield Tables for Conifers in Great Britain)								
Top height (feet)	*Scots pine*	*Corsican pine*	*European larch*	*Japanese larch*	*Norway spruce*	*Sitka spruce*	*Douglas fir*	*Western hemlock*	*Abies grandis*
21–30	75	100	55	60	80	85	55	85	55
31–40	122	144	72	86	130	115	97	124	106
41–50	147	156	87	101	162	137	118	139	135
51–60	170	171	100	111	191	149	132	156	160
61–70	190	179	113	120	214	154	144	173	175
71–80	202	188	125	129	231	157	152	189	182
81–90	..	..	134	136	..	158	163	204	187
91–100	..	..	142	..	..	160	170	..	189
101–10	..	..	..	..	..	162	177	..	190

Unlike other methods of estimating increment, yield tables provide some ready-made basis for assessing future increment. The uncertainties inherent in applying yield table data to particular stands are, however, magnified when one has to

make the additional assumption that a stand which corresponds with a yield table entry will continue to follow the pattern of growth embodied in that yield table.

(*d*) *From measurements within the tree.* Yield tables may be used to give an immediate *estimate* of increment, while successive enumerations enable increment to be *measured*, but one has to wait a number of years for the answer. In order to obtain an immediate *measurement* of increment it is necessary to measure the changes in the three components of volume—namely basal area, height, and form factor in a statistically adequate number of plots, over a period of time, usually the preceding 5 or 10 years. This is most easily done with mature or semi-mature crops, where changes in height and form factor have become small and where trees are no longer being removed as thinnings. Under such circumstances volume increment is very closely related to basal area increment, which may be calculated quite easily from increment cores. In younger crops, however, the method is complicated by the fact that the trees are growing not only radially but also in height and increasing in form factor. Furthermore, the trees standing at any given time are the survivors of a larger number, some of which will have been removed as thinnings during the period over which the increment is being measured. There are also considerable practical difficulties in measuring the height increment of standing trees for the preceding 5 or 10 years, since the size of the sample required precludes felling the sample trees. It is even more difficult to measure changes in the form factor of standing trees—so difficult in fact as to be quite impracticable on a large scale. Fortunately, however, there is a close relationship between form factor on the one hand and species and top height on the other, so that adequate estimates of form factor at different top heights may be obtained from form factor tables. The greatest difficulty arises from the removal of trees as thinnings during the period for which a measurement of increment is required. If the basal area increment of the present crop is measured for, say the past 10 years, the result will not give the total productive capacity of the site. Although the trees standing now may occupy the site fully, 10 years ago they were only a proportion of a greater number of trees, all of which were putting on increment (Fig. 1). The principal reason for measuring increment, however, is as a basis for forecasts of future increment and the surviving trees will supply all the increment for the next 10 years. If, therefore, an increment percent. can be calculated and applied to the existing growing stock, it may be possible to arrive at a basis for estimating future increment. It is still necessary, however, to decide the probable future growth curve of the crop, some indication of which may be obtained from yield tables.

In fact future growth is unlikely to continue in a straight line (*BFD* in Fig. 1). In the example shown the basal area increment percent. shows a slight reduction for the period year 0 to year 5 although the volume increment percent. increases slightly. This is because periodic annual basal area increment generally culminates at an earlier age than periodic annual volume increment. This young Sitka spruce stand had passed the period of maximum periodic annual basal area increment but had not reached the point of maximum periodic annual volume increment. In the example the pattern of future growth was known but in practice this will not be the case. Some indication may be obtained by introducing one or more

additional points on the line *BF* by measuring, for example, the ring widths for the previous 5- or as well as the previous 10-year period. Alternatively yield table patterns of growth may be used to extrapolate the line *BF* to years 5 or 10.

In order to avoid the practical difficulties of measuring height and form factor increment, attempts have been made to produce increment percent. tables from yield tables, e.g. those of Prodan (1949) derived from Schneider's tables. These

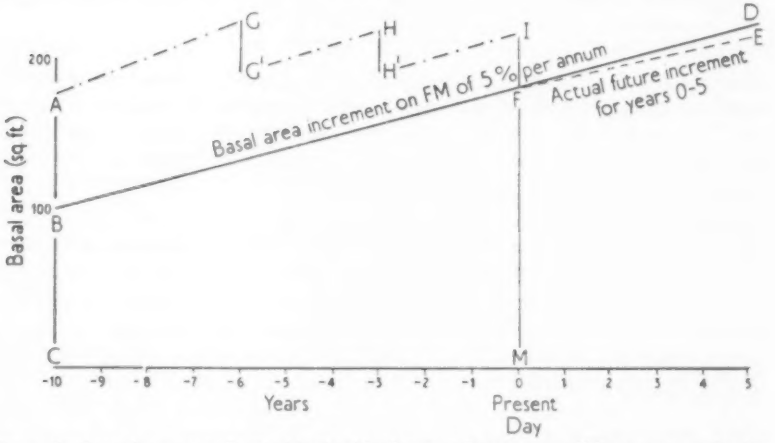

FIG. 1. Basal area increment of a stand in the thinning stage (based upon a Sitka spruce sample plot, quality class I, between the ages of 18 and 28 years).

FM, the basal area per acre of the crop at the time of increment boring (year 0).

BC, the basal area per acre of the present trees 10 years earlier (year −10).

AC, the basal area per acre of the total crop 10 years earlier (year −10).

AB, the basal area per acre of the trees which were present in year −10 but which were removed in thinnings during the period year −10 to year 0.

GG', *HH'*, and *IF*, the basal area per acre removed in thinnings during the period year −10 to year 0. This total basal area equals the basal area *AB* plus the increment on it for the 10-year period.

FD, direct extrapolation of the basal area C.A.I. percent. of the present growing stock.

FE, shape of actual future growth curve.

tables incorporate the height growth and form factor assumptions of the yield tables and give estimates of increment percent. if the following variables are known: (*a*) basal area per acre, (*b*) average ring width of the mean basal area trees for the past *n* years. Prodan's tables rely, therefore, upon a predetermined basal area/form height relationship and are probably applicable only to a particular thinning régime in south-west Germany. The idea might, however, be applied to any given combination of species, site, and treatment.

10. *Choice of enumeration method*

Two different types of information are required for long- and short-term planning. For medium and long-term planning and for long-term silvicultural

control, the forest manager must have reliable estimates of current and future volumes and increments by administrative units such as forests, sections, and beats, or by management units such as working circles and felling series. This 'extensive' type of information must be strictly comparable from one decade to the next and its precision must be known.

For short-term planning (say up to one year ahead) and for month-to-month management, additional 'intensive' information is required by working blocks, compartments, and sub-compartments.

The 'extensive' long-term planning information may be obtained most economically from a system of temporary, stratified, random enumeration plots. The method of stratification will depend upon the variability of the crops present in the forest and the type of information required, but will generally be by species and age classes. The sampling will be planned to provide results of satisfactory precision for the various units such as felling series or beats, for which individual information is required. Planning of forest operations is normally based in the first place on administrative or supervisory units and within them on management units. At the present time in Britain, increment is estimated from yield tables used in conjunction with sample plots, but the successive volume enumerations of known precision, carried out at something like 10-yearly intervals, can be used in conjunction with routine forest records of production, to check forecasts of increment and to provide retrospective measurements of increment. It is hoped to develop methods for obtaining immediate measurements of increment from increment cores, height analyses, and form factor tables and to use these measurements for forecasting future increment. The matter is complex, however, and has not yet passed the development stage. It may ultimately be possible to produce tables of the 'Prodan' type for various geographical regions.

Intensive surveys of the standing volumes and increments of individual compartments and sub-compartments cannot be carried out by a system of enumeration plots, because the number of plots required to obtain reasonable estimates would be far too large. Moreover, it is unnecessary for successive estimates to be strictly comparable. Therefore a system of visual estimating is the most practicable method. This may be done at negligible cost at the time of a working-plan survey in addition to the sample survey, the latter providing an overall check on the accuracy of the visual estimates.

The problems of yield control which many foresters in Great Britain are now having to face for the first time are fundamental to forest management. The mensurational aspects of yield control are, however, of less importance than the more fundamental questions of what decisions we need to make for efficient management and what data we need to make them. It is all too easy to collect data for data's sake and no forest enumerations should be carried out until the aims and objects of the enumeration are clearly defined and understood.

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THE INFLUENCE OF PRUNING ON THE GROWTH OF CONIFERS

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SUMMARY

The author sifts briefly the principal literature on pruning. He analyses the conclusions reached and in particular, in agreement with Lehtpere on Douglas fir (*Pseudotsuga taxifolia* Brit.), disputes the maxim held by some that the removal of up to one-third the length of the live crown has no adverse effect on diameter increment, though he agrees it may have little effect on height growth. To his analysis of Ladefoged's paper dealing with Norway spruce (*Picea abies* Karst.), he adds, in a table, his own estimate of the probable percentage contribution made to stem increment by each of eleven successive whorls of branches from the top downwards and considers that these percentages should apply also to other young coniferous species given a crown ratio of about 0·6. His main conclusions are listed and the paper ends with a comprehensive bibliography.

INTRODUCTION

THE question has often been asked, how far can conifers, and especially Douglas fir, be pruned without reducing increment; the results of different experiments often seem contradictory. In this paper the most important or best known of the existing experiments are outlined and discussed briefly, and to a certain extent brought into harmony, giving a reasonably consistent overall picture of the relationships in question. The very numerous treatises on the topic in general have not been taken into consideration, and disbudding experiments have been disregarded.

DOUGLAS FIR

Lehtpere (1957) reports an experiment involving heavy pruning of young Douglas fir. The experiment was established in March 1953 in North Wood at Dartington in South Devon in a row-by-row mixture of Douglas fir and Sitka spruce (*Picea sitchensis* Carr.) planted in 1942 at 6 by 6 feet spacing with a few redwoods in the Sitka rows. The Douglas firs had made a good start and had suppressed many of the Sitka spruces with the result that in 1957 the latter provided only 10 per cent. of the trees in the canopy. The plantation was brashed up to 7 feet in 1950, and heavily thinned in 1950–1. According to sample plot data of November 1955, the plantation corresponded to 1st quality class in the Forestry Commission Revised Yield Tables for Douglas fir and had about the same mean annual increment.

In 1952–3, 200 Douglas firs per acre were marked for pruning. Of these, 50 pairs from all diameter classes were taken for the experiment and divided at random into two groups. One group of 50 trees was retained as control, the other pruned up to 16 feet, i.e. to about half the tree height. On the average green branches were

removed from a height of 8·5 to 16 feet above ground, thereby reducing the crown length by 32 per cent. From most of the trees three lower whorls were removed and on the average five whorls left.

The main results of the experiment are summarized by Lehtpere in his table II These are given in Table I below.

TABLE I. *Girth measurement at breast height and at 15 feet from 1953 to 1955 (Lehtpere)*

No. of trees	*Mean girth at breast height (in.) March 1953*	*Girth increment at breast height (in.)*			*Mean girth at 15 ft. (in.) March 1953*	*Girth increment at 15 ft. (in.)*		
		1953	*1954*	*1955*		*1953*	*1954*	*1955*
50 pruned trees .	17·25	1·35	1·20	0·96	11·71	2·20	1·50	1·14
50 control trees .	17·25	1·71	1·33	0·90	11·37	2·27	1·57	1·14
Difference .	0	−0·36	−0·13	+0·06	0·34	−0·07	−0·07	0

Statistical analyses have been made, and the results can be summarized briefly as follows:

1. At the end of the first growing season following pruning a significant reduction in the girth increment at breast height was obtained for all girth classes.
2. In the second growing season this reduction was only found in the smaller girth classes.
3. In the third growing season the growth of the pruned trees at breast height was a little but not significantly better than that of the control trees.
4. There was no significant reduction in the girth increment at 15 feet, i.e. above the removed branches.
5. Height growth was not affected by pruning.

As might be expected it was eventually found that scars of removed branches healed sooner on the faster-growing trees.

Since, on the average, three lower whorls were removed at the start, and the observation lasted 3 years without thinnings, it is not surprising that the depressing effect of pruning on increment had disappeared by the third year, when the three lost whorls had been replaced by three new whorls.

Stein (1955) has published the results of a study, started in 1937, to measure the effect of pruning the live crown of young Douglas fir to different heights. The trees were remeasured for the second time in the summer of 1950, 13 years after the original treatment, and the conclusion reached that 'one-third of the live crown length can be removed without harmful effect'.

This result seems to be in clear contradiction to that obtained by Lehtpere, but let us consider it a little more closely on the basis of the following details.

Two hundred dominant and codominant crop trees were pruned in 1937 in a 28-year-old even-aged stand of pure Douglas fir varying in density from moderate to well-stocked, and of site class IV according to McArdle and Meyer.

Pruning treatments consisted of the removal of dead limbs only (control) and the removal of dead limbs plus 25, 50, and 75 per cent. of the live crown length. One of the four pruning treatments was assigned at random to each tree giving four groups each of about 50 trees. All trees were tagged and measured for d.b.h., total height, and height to the first live limb.

Among other results, the following were obtained.

TABLE II. *Results of four different pruning treatments (Stein)*

Item	*Time*	*Extent of pruning*			
		Dead limbs	*25% live crown*	*50% live crown*	*75% live crown*
Number of trees alive, 1950	..	49	49	45	49
Mean d.b.h., inches	1937	5·48	5·65	5·16	5·59
	1950	7·58	7·95	6·96	6·61
Mean diameter growth, inches	1937–50	2·10	2·30	1·80	1·02
Adjusted mean diameter growth, inches	1937–50	2·10	2·23	1·92	0·98
Diameter growth in % of dead-limb pruning	1937–50	100·0	106·5	91·7	46·9
Mean total height, feet	1937	40·6	40·8	39·7	40·9
	1950	60·6	61·8	57·6	54·2
Mean height growth, feet	1937–50	20·0	21·0	17·9	13·3
Adjusted mean height growth, feet	1937–50	19·9	20·9	18·1	13·2
Height growth in % of dead-limb pruning	1937–50	100·0	104·9	90·8	66·4

Since the data for the period 1937–50 showed that diameter growth was positively related to initial diameter and height growth to initial height, growth was corrected for initial diameter and height by an analysis of covariance, and treatment means were adjusted to a common initial diameter and height. The differences between adjusted means were then tested for statistical significance by the 't' test.

The data presented in the table seem to indicate that more growth occurred on the trees when 25 per cent. of the live crown was pruned than when only dead limbs were removed. Although the difference is not significant statistically, the author suggests that it may be due to a depressing effect of the lower branches on growth owing to their 'high ratio of food-using cambium to food-producing needles'.

However, it must be remembered that any possible depressing effect of the pruning of 25 per cent. of the living crown may probably have already been exhausted in the third year of growth following pruning by the formation of new whorls, as we saw was the case in Lehtpere's experiment, and further, that the experiment is not sufficiently precise to reveal small differences in increment

which might be caused by differences in treatment, because the variation in tree size was extremely large at the start (heights varying from 28 to 59 feet), and means, on such a basis, are rather unreliable quantities.

In stands of such a dissimilar character it is not sufficient experimentally that the mean height at the start be the same for the different treatments. The trees must also show the same variation in dominance, which was not the case here. It appears from Stein's table 5, not reproduced here, that among the 'dead limb pruned' trees, only 68 per cent. were dominant at the start, whereas among the '25 per cent. pruned', 80 per cent. were dominant, which difference may have influenced the result.

As to the early exhaustion of the pruning effect, the following calculation may be made. If in Stein's experiment we assume the same depressing effect of pruning during the first 2 years as found by Lehtpere, this would mean a reduction of 16 per cent. in the normal diameter increment of the first 2 years (cf. Table I above). If further we assume a constant and normal diameter growth after the first 2 years, the reduction in total diameter increment over the 13 years (1937–50) due to pruning will be 2·5 per cent. As a matter of fact, however, from Table III above it appears that diameter increment has tended to diminish during the experiment. Allowing for this, the 2·5 per cent. becomes 3·0 per cent.

Now it must be remembered that the measurement of diameter is not without errors in itself. Stein does not give mensurational details, but if, for example, measurements were rounded off to the nearest inch, this would yield a mean error of $\frac{1}{3}$ inch on the single diameter and of $\frac{1}{21}$ inch on a mean of 50 diameters. Accordingly a 'rounding off error' of over 2 per cent. in the mean diameter growth might be expected in 5 out of 100 cases. There are other well-known sources of error.

Even two groups, each of 50 trees, growing under the same conditions and starting with the same mean height, mean diameter, and variation in dominance would not be expected to have exactly the same mean height and mean diameter 13 years later, and in this case one group seemed handicapped from the start by a smaller percentage of dominant trees.

It is interesting here to compare the results of the first remeasurement of the pruning study made in 1943 and reported by Isaac in 1945 (cf. Table III below).

TABLE III. *Mean annual diameter and height growth, by periods (Isaac)*

(Based on unadjusted measurements of 192 trees alive in 1950.)

	Mean annual diameter growth		*Mean annual height growth*	
Extent of pruning	*1937–43*	*1943–50*	*1937–43*	*1943–50*
	Inches		*Feet*	
Dead limbs . .	0·19	0·14	1·5	1·5
25% live crown .	0·20	0·16	1·6	1·6
50% live crown .	0·16	0·12	1·3	1·4
75% live crown .	0·07	0·08	0·9	1·2

It will be seen that the apparent superiority of the 25 per cent. pruning compared with no pruning was about half as great during the first 6 years as during the following 7 years, which is in agreement with the supposition that pruning may have depressed growth during the first 2 or 3 years.

It may be objected that Stein's stand was older than Lehtpere's, and that a possible depressing effect of pruning, therefore, could not be exhausted so quickly as supposed by the formation of new whorls. It must be remembered, however, that we are comparing a 32 per cent. pruning by Lehtpere with only a 25 per cent. pruning by Stein, which must compensate fairly well for the difference in initial height.

The experiment reported by Stein does not include pruning effects at levels other than at breast height.

The preceding discussion leads to the conclusion that Stein's results do not necessarily contradict those obtained by Lehtpere, as a depressing influence of pruning during the first few years of Stein's experiment may easily have been hidden under the bulk of later increment and the various sources of error.

In the following paragraphs we shall try to examine the probability of such a depressing influence in the light of other experiments.

Weck (1938), in agreement with Stein, concluded that pruning of up to one-third of the live crown has no significant and important effect on Douglas fir growth, provided that a crown ratio of at least 40 per cent. is left. ('Grünästung, die durch Entfernung von höchstens $\frac{1}{3}$ der grünen Krone die Gesamt-Kronenlänge auf nicht weniger als $\frac{2}{3}$ der Schaftlänge verringert, hat keine eindeutige und belangvolle Minderung der Zuwachsleistung zur Folge.')

To appreciate what this really means, we must look closer at his results, which were obtained in a 22-year-old stand that had been pruned in the spring of 1936, the percentage of living crown taken varying considerably.

In the autumn of 1937 he chose for further examination 6 unpruned trees, 5 trees from which 50–60 per cent. of the living crown had been removed and 4 trees from which 15–35 per cent. of the living crown had been removed. The trees were selected from dominant trees near to each other; in many cases the stems compared were adjacent.

For each stem the following measurements were made:

1. Total height in half metres.
2. D.b.h. over bark by caliper, rounded off to the nearest half centimetre.
3. Length of living crown before and after pruning in tenths of total height.
4. Diameter and diameter increment under bark by increment borer at breast height on the south and on the east sides.

The results obtained are given in Table IV.

The generalized conclusion drawn by Weck is hardly justified on the basis of so little material. The average heights of the three groups differ by about 10 per cent. and the mensurational methods used are rather rough. What the increment was in other parts of the stem was not determined, and even if the increment at

breast height can be considered representative of the rest of the stem and the most accurate mensurational methods had been applied, one could not expect significant mean values from an average of five stems in each group.

Weck's experiment does not exclude an important depressing effect following the 15–35 per cent. pruning of the same order of magnitude as found by Lehtpere.

TABLE IV. *Details from Weck's experiment (the sign Δ G represents annual basal area increment in mm.²)*

	Autumn 1937		*Length of living crown in tenths of total height*			*ΔG 1936–7 as % of ΔG 1931–5*
Item	*Total height*	*D.b.b. cm. under bark*	*Before pruning*	*After pruning*		
1	15·5	15·5	Not pruned			179
2	16·0	14·0				134
3	15·5	13·0				115
4	15·0	16·3				115
5	16·5	16·0				128
6	15·5	17·6				141
Average	15·7	15·4	Not pruned		Total ΔG 1936–7 as % of total ΔG 1931–5	138
7	16·5	16·0	6	3·0		99
8	15·0	15·0	6	2·5		100
9	16·0	16·6	6	2·5		95
10	16·0	17·0	6	2·5		95
11	16·5	13·8	5	2·5		95
Average	16·0	15·9	50–60 % of the living crown pruned		Ditto	97
12	18·5	21·6	7	5		118
13	17·5	15·8	6	5		118
14	16·0	12·8	6	4		180
15	18·0	18·2	6	4		114
Average	17·5	17·1	15–35 % of the living crown pruned		Ditto	126

OTHER SPECIES, MAINLY CONIFERS

Pruning experiments on Douglas fir other than those mentioned above are barely reported in the generally accessible literature. However, to illustrate the probability of a basic depressing (or positive) effect of pruning up to one-third of the living crown it may be worth while giving a short review of certain pruning experiments on other conifers.

Bennett (1955) describes an experiment with 5 levels of live crown removal in slash pine (*Pinus elliottii*), namely: none, 35 per cent., 50 per cent., 65 per cent.,

and 80 per cent. Treatments were replicated in 5 blocks each of 5 randomized plots. The plots contained an average of 36 trees from which 10 were selected for treatment.

The experiment was established in two plantations, one 5 years of age, 15 feet in height, with spacing 10 by 10 feet, the other 11 years old, 30 feet in height, with spacing 15 by 15 feet.

Pruning was carried out in the spring of 1948 and increment in height and d.b.h. measured separately for the years 1948, 1949, 1950, and 1951.

There was little or no effect on height growth.

Diameter growth was, on the other hand, already reduced significantly in 1948 in both stands by removal of 35 per cent., and in 1949 significantly by removal of 35 per cent. in the 11-year-old plantation and 50 per cent. in the 5-year-old plantation.

Dahms (1954) reports a pruning experiment on *Pinus ponderosa* Laws made in a 55-year-old even-aged stand of site class IV. In each of 4 plots 4 treatments (unpruned, one-quarter, one-half, and three-quarters of living crown removed) were assigned at random to each of 24 trees.

Growth in height and diameter was determined for the first and second 5-year periods after pruning. A definite recovery from the first to the second period was established.

During the first 5 years, pruning of one-quarter of the living crown reduced the increment in diameter and height by about 5 per cent., pruning of three-quarters by about 10 per cent.

Labyak and **Schumacher** (1954) have tried to establish the live-crown ratio which, after pruning, would result in maximum volume growth of the main stem below the crown of an individual tree. The experiment was set up in the autumn of 1934 in a relatively open stand of 15-years-old Loblolly pine (*Pinus taeda* L.).

Nine treatments were imposed so as to leave live-crown ratios of 10 to 90 per cent. at 10 per cent. intervals. Each pruning was applied to 30 trees dispersed throughout the stand. 'Second and third prunings were made after the 1939 and 1944 growing season, so as to maintain the initial crown ratios.' It is evident, however, that since the pruned branches were probably already compensated for by new whorls 3 years after pruning, the average live-crown ratios were, in reality, considerably greater than supposed.

Ten trees in each of the nine crown-ratio classes were finally felled for stem-analyses. In 1949 the trees were 55 feet high. Statistical treatments including regression analyses were applied and an equation was found for the contribution of a single branch P to the current annual cross-sectional area growth of the main stem at P, where P is the distance from tree-tip to branch, expressed as a proportion of main-stem length from tip to stump. *Inter alia* it was found that a live-crown ratio of 0·4 produced maximum clear volume on the tree bole below the crown, whereas maximum total stem volume increment was found with the highest live-crown ratios.

McClay (1953) gives some results from a pruning study in open-grown loblolly pine, 10–15 years old and green to the ground. These are shown in Table V.

Pruning was begun in 1945 (summer and winter) and repeated in 1948 and 1950 to maintain the crown ratio.

It seems probable that pruning in the middle of the summer would give a smaller reduction of growth than pruning during the foregoing winter, since the branches to be pruned may already have contributed considerably to growth.

Young and **Kramer** (1952) made weekly measurements of height and diameter growth over two growing seasons on 18 14-year-old loblolly pines, about 35 feet tall and 6 inches in d.b.h. The 18 trees were divided into 6 blocks each containing 3 trees as uniform as possible in shape and size, these being pruned so that the

TABLE V. *Loblolly pine* (*McClay*)

Pruning up to	*Average annual growth during 6 years after pruning*	
	Diameter (*in.*)	*Height* (*ft.*)
Two-thirds total height, summer	0·52	2·9
Half total height, winter	0·58	2·9
Half total height, summer	0·64	3·1
No pruning	0·66	3·2

amount of crown left occupied 50 per cent., 35 per cent., and 20 per cent. of their total height.

Diameter measurements were made at breast height, 50 per cent., 65 per cent., and 80 per cent. of the total height.

Trees with 50 per cent. crowns grew most and those with 20 per cent. crowns grew least in diameter at all but the uppermost point. Diameter growth decreased with increase in distance below the crown for all sizes of crown, but the decrease in percent. was three times greater in trees with 50 per cent. crowns.

As the lengths of crowns before pruning were about 50 per cent. of the total height (exact figures are not given), it is seen from the graphs that a 30 per cent. pruning (from 50 to 35 per cent. of the total height) has reduced volume increment considerably.

Height increment was not affected.

Nägeli (1952), reporting on the pruning experiments of the Swiss Experiment Station, found no significant influence of pruning on increment. This was a natural consequence of the experimental methods and conditions. Four pruning grades were applied: (1) no pruning at all, (2) pruning of dead limbs with the exception of the two uppermost whorls, which were retained to make sure that no living branches were taken, (3) pruning of all dead limbs plus two live whorls, and (4) pruning of dead limbs plus four live whorls.

As a live whorl, every whorl was considered which contained at least one needle-bearing branch. All smaller branches between the whorls were removed up to the first live whorls remaining.

The experiment was made in 5 stands, the number of treatments varying

between 2 and 4 in a single stand. Each treatment was concentrated in a particular stand. Of the 17 plots, 5 were not pruned at all, in 5 dead limbs were removed, in 5 dead limbs plus 2 live whorls, and only in 1 plot was the so-called 'heavy pruning' tried.

Since total height was not quite the same in the plots to be compared, since at the start the average age of the plots was 43 years, their average heights 17–18 m. and the pruning applied consequently very light, and, finally, since comparisons were made between increments over periods of 4–6 years after pruning, it is not to be wondered that no significant influence of pruning was found.

Helmers (1946) selected 56 pairs of stems in a 20–30-year-old Western white pine stand (*Pinus monticola* Dougl.) with about the same height, diameter, and general appearance. One of each pair was pruned and the other left unpruned as control. The pruning removed 17–69 per cent. of the live crown length. Of the 17 trees from which more than 55 per cent. was removed, 8 died. No trees pruned less than 55 per cent. died.

Increment during the first year was determined. One-fifth pruning had no significant effect on height growth, two-fifths caused a reduction of about 10 per cent., and three-fifths a reduction of about 40 per cent.

Diameter growth was reduced 5 per cent. following one-fifth pruning, 25–30 per cent. following two-fifths pruning, and 70–75 per cent. following three-fifths pruning.

Buchanan (1944) found that pruning 25 per cent. or more of the living crown reduced diameter increment in young Western white pine. During the 2 years following pruning the increase in diameter of the pruned trees, both at 1 foot and at 4·5 feet from the ground, was in all cases less than that of the unpruned controls.

The loss of increment at 1 foot for pruning 25 per cent. of the living crown was barely statistically significant ($P = 0{\cdot}09$), but for pruning 50 and 75 per cent., highly significant ($P < 0{\cdot}01$). At 4·5 feet the effect of pruning was relatively less pronounced than at 1 foot but was highly significant in all cases.

The number of pruned trees, however, was only three for each degree of pruning.

Bull (1943) reports experiments set up in Southern Mississippi in an open longleaf pine stand (*Pinus palustris* Mill), varying in height from 15 to 48 feet. After 5 years it was found, among other things, that 'the frequently recommended practice of removing one-third of the live crown' resulted in a total loss of 'slightly more than one year's growth for an open grown tree'.

Barret and **Downs** (1943) tried three degrees of pruning on 94 trees of Eastern white pine (*Pinus strobus* L.). The percentage of living whorls removed, with the subsequent diameter and height growth and the crown ratio, are given in Table VI.

A whorl was considered living if 50 per cent. or more of the limbs were alive.

Craib (1939) records results of pruning live branches of young pines planted in S. Africa. Removal of 25 per cent. had no significant effect. Removal of 50 per cent. had considerable depressing effect on diameter. Removal of 75 per cent. depressed both diameter and height growth (*Pinus patula*, *P. taeda*, and *P. caribaea*).

Lundh's (1924) investigation into the effect of pruning Scots pine (*Pinus sylvestris* L.) about 100 years old is well known in Europe. He found that diameter growth was reduced during the first 10-year period after pruning but was considerably augmented during the next 20 years. Height increment, on the other hand, was somewhat stimulated during the first 10 years, but volume increment reduced.

Since Lundh's material is rather meagre and the crown ratio before and after pruning is not known, this investigation cannot contribute much to the solution.

TABLE VI. *Eastern white pine* (*Barret and Downs*)

Treatment	*Diameter growth (in.)*			*Height growth (ft.)*			*Crown ratio*	
	2 years	*4 years*	*5 years*	*2 years*	*4 years*	*5 years*	*Dir. after pruning*	*5 years later*
No pruning	0·34	0·96	1·28	3·2	7·2	9·0	70	63
Light pruning, 6–15%	0·34	0·97	1·28	3·3	7·4	9·1	65	64
Moderate pruning, 16–25%	0·32	0·94	1·24	3·2	7·3	9·1	59	63
Heavy pruning, 26–35%	0·29	0·88	1·18	3·0	7·0	8·7	52	61

TABLE VII. *Reduction of basal area increment* (*Zederbauer*)

During the summer of	*Relative figures for basal area increment*		
	Douglas fir		*Norway spruce*
	1906	*1907*	*1906*
Pruning of dead limbs only	100	100	100
Pruning of one-third of live crown	47	36	89
Pruning of one-half of live crown	27	21	81

Zederbauer (1909) made pruning experiments for the Austrian Experiment Station and found among other things, that as a mean of eighty, 25–30-year-old beeches (*Fagus sylvatica* L.), removing half the live crown only reduced the basal area increment of the first year by about 10 per cent.

As a mean of six 20–21-year-old Douglas firs and of an unspecified number of Norway spruce (age not given) he found the effect of pruning during the first summer as shown in Table VII.

Since almost no details are given, and since the general impression of the experimental standard is not quite reassuring, these figures must be regarded with some reservation.

Forestry Abstracts reports briefly on several other experiments, but the author has not been able to see the original publications, and the details given do not make it possible to judge the methods and results.

In some cases a small reduction in diameter growth was found even after pruning one-third of the live-crown length, but in many cases up to 50 per cent. of the live-crown length could be removed without apparently retarding annual height and diameter growth. In certain Czechoslovakian and Russian publications it is even reported that pruning of lateral buds and pruning of up to two-thirds of the live-crown length increased both height and diameter growth.

In these last cases, either replications were not made or a small pruned plot has been compared with a whole unpruned stand.

OTHER EXPERIMENTS

The preceding review of the literature has shown that a majority of authors have found a depressing effect on diameter increment by pruning of one-third of the living crown or more, even though the effect was generally calculated as a mean of several years after pruning.

In the two cases where pruning of 25 per cent. of the live crown gave greater increment than no pruning (Stein), or where pruning of up to one-third of the live crown gave no significant effect (Weck), it could be shown that either the conclusion was not justified or the result obtained did not exclude a depressing effect during the first years after pruning.

Therefore, in confirmation of Lehtpere's results, it may be considered most probable that as a rule such a depressing effect does take place. The experiments reported have been mainly made on Douglas fir or with various American pine species, but have also been made on beech and Norway spruce, and it seems most likely that the effect in question is independent of the species, although this cannot be considered as proved.

When in certain cases a depressing effect has not been observed, it is probably because the investigators have considered the matter as follows: pruning produces a considerable improvement in wood quality, and, if the reduction in increment effected by green pruning is so small that it cannot be established by ordinary rough mensurational methods, it is of no importance.

Later we shall see to what extent this view is justified, but first let us look at certain older and more recent experiments which have been set up expressly for the purpose of elucidating the importance of every single whorl to the increment.

Hartig (1872) applied varying degrees of green pruning from below to 20–25-year-old densely growing Weymouth pine (i.e. Eastern white pine) and found the results shown in Table VIII.

Hartig draws the conclusion that the stand reacted with a minor loss of increment for every pruning that removed more than one or two of the undermost, sparsely needled whorls, but it seems justified to conclude along with Cieslar (1904), that these two whorls probably were also of positive importance to the growth of the tree.

Hartig (1901) later reported a case where two 99-year-old isolated beeches had half their live crowns removed from below, with the result that the average volume increment of the stem during the following 9 years was not diminished compared

with the previous 9 years. It must be remembered, however, that the volume increment of a tree is normally increasing steadily.

In another case an isolated oak was deprived of half its foliage from below and maintained its volume increment during the following year. Hartig suggests nutrient reserves as part of the explanation.

These individual cases later played a major role in discussions, but it must be remembered that in other cases the results were otherwise as a consequence of the great, often inexplicable, individual variations in the growth of trees. Hartig himself (1901, p. 50), on the basis of experiments, pronounced the view that pruning

TABLE VIII. *Increment percent. of d.b.h. before and after pruning. Autumn 1868 (Hartig)*

Number of live whorls was 9–10. 1868 was a very dry year.

Year	*Last years top-shoot*	*Pruning from below of live whorls*								*Not pruned*
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	
1865 . .	9·8	..	12·7	12·9	10·0	7·8	12·8	8·7	13·8	12·4
1866 . .	10·2	..	14·3	13·1	10·1	7·9	11·5	9·7	14·0	13·2
1867 . .	12·0	12·9	16·0	14·9	11·8	9·2	12·7	12·4	19·8	17·9
1868 . .	6·3	6·3	7·6	8·0	6·6	7·1	7·0	6·1	9·3	8·9
Sum, 1866–8 .	28·5	..	37·9	36·0	28·5	24·2	31·2	28·2	43·1	40·0
1869 . .	0·4	0·7	1·3	4·0	3·8	5·2	7·1	6·1	11·8	11·3
1870 . .	1·3	3·3	2·8	5·9	3·4	4·8	7·0	8·2	12·0	14·7
1871 . .	2·4	..	4·4	9·4	6·4	8·4	9·8	9·4	12·5	14·7
Sum, 1869–71 .	4·1	..	8·5	19·3	13·6	18·4	23·9	23·7	36·3	40·7
Number of stems . .	3	1	4	3	3	1	3	2	2	3

in a closed stand always has a depressing effect on increment 'if leaves are removed which are exposed to light, because as a rule, mutual shading prevents excessive leaf quantities'.

Hartig also investigated the effect of pruning on diameter growth at different heights above ground and found that the depressing effect of pruning was always revealed first and foremost in the lowest part of the bole. The removal of one or two live whorls could already be detected at breast height, and if more than half of the live whorls were removed no increment at all took place at the base of the bole, whereas immediately under the live-crown increment was usually maintained. When increment recovered during the years following pruning, the lower parts of the bole were always the last to regain vigour.

As to height growth, Hartig found that in the dry year of 1868, just before the pruning, the increment had been normal. In 1869 the unpruned or lightly pruned trees had strikingly short shoots, whereas the shoots of the strongly pruned trees were normal; Hartig's explanation for this is that the scarce reserve substances following the dry year of 1868 were only sufficient when available to the

uppermost whorls. Apart from this no definite effect of pruning on height growth was observed.

Kienitz (1928) removed in 1897 (and 1887) 1–5 live whorls from *c.* 25-year-old Norway spruce in a somewhat confused experiment with originally 10 plots each of 300–800 sq. yds. Measurements showed that the pruned trees had a somewhat smaller average increment in d.b.h. during the following 10–15 years compared with controls of the same stem- and diameter-classes. In one case the removal of a single whorl seems to have reduced increment (plot VI), but in other cases it is the other way about. Increment in the years before pruning was not examined. Kienitz was convinced that green pruning primarily promotes the increment of dominant trees but reduces the increment of suppressed stems. Measurements confirm the latter supposition but provide no evidence for the former. This experiment suffers from the same weakness as many others, namely that only mean increments over long periods after pruning are compared.

Diameters and diameter increments were also measured at heights of 4·5 m. and 3·5 m. above ground, but it is not possible to draw conclusions from the rather incomplete material. In his introduction Kienitz gives a valuable synopsis of the history of the pruning question.

Ladefoged (1946) carried out in 1938 a very detailed experiment in a 21-year-old spruce stand near Copenhagen. The stand had been thinned vigorously for several years and had a crown ratio of 0·6–0·7. The total height of the stand varied from 8–16 m. with a mean of 10·4 m.

In November 1938, directly after an ordinary thinning, 75 well-formed and healthy trees were selected for the experiment and numbered. From these trees 0, 1, 2, 3, 4, 5, 6, and 7 live whorls were removed from below in 8 groups respectively, each comprising 9–10 trees. Heights of 1·3 m., 3·3 m., and 5·3 m. above ground were marked with yellow rings round the stem, and the diameters measured.

For the 66 trees from which live whorls had been removed, one further whorl was taken from below in every subsequent year in order to keep the number of live whorls constant during the experiment; in reality this means a small annual reduction in the crown ratio and a small annual strengthening of the relative pruning effect.

Measurements were made again in the spring of 1939, as a control, and in every subsequent year during the experiment with the exception of 1942.

After 5 years, in the spring of 1944, the experiment was terminated.

Cross-sections at 1·3 m. height were cut off from all the experimental trees, and for a few, regular stem analyses were also made.

The experimental material suffers from the fault that initial mean heights and initial d.b.h. were not quite the same for all the eight groups representing different numbers of live whorls removed.

Trees with 4–6 live whorls left in 1944 had an initial d.b.h. of 11·6 cm., trees with 7–10 live whorls 12·1 cm., and trees with 11–14 whorls 12·8 cm. In order to eliminate as far as possible this source of error, all increment values were calculated (for each single tree) as:

$$\frac{\text{increment } 1939\text{–}43 \times 100}{\text{increment } 1934\text{–}8}.$$

It was found that height increment was comparatively little influenced by pruning (a reduction of about 20 per cent. with the strongest prunings).

Regression calculations showed that only 12 per cent. of the total height variation was due to the varying number of whorls.

The influence on basal area increment is shown in Table IX below, which indicates values obtained for the ratio.

$$\frac{\text{(Basal area increment 1939–43)} \times 100}{\text{Basal area increment 1934–8}}.$$

TABLE IX. *Influence on basal area increment (Ladefoged)*

(The figures within parentheses indicate number of trees.)

Number of live whorls before pruning	*Number of live whorls removed*								*Number of trees*
	0	1	2	3	4	5	6	7	
8	76 (1)	..	..	..	..	..	..	..	1
9	..	..	..	85 (1)	..	..	..	..	1
10	..	71 (3)	..	..	47 (1)	5 (1)	15 (2)	..	7
11	100 (1)	90 (1)	77 (4)	36 (2)	64 (2)	19 (1)	4 (1)	10 (1)	13
12	95 (2)	75 (4)	60 (2)	67 (2)	64 (3)	28 (4)	36 (3)	13 (2)	22
13	108 (3)	110 (1)	89 (2)	63 (2)	66 (2)	62 (1)	39 (2)	16 (3)	16
14	92 (2)	..	105 (1)	..	80 (1)	..	38 (2)	53 (2)	8
15	..	..	..	76 (1)	..	..	..	46 (1)	2
16	..	..	..	..	..	..	..	23 (1)	1
Number of trees	9	9	9	8	9	7	10	10	71
Average	97	79	79	62	64	28	30	26	..
$\frac{\text{(V.i. 1939–43)} \times 100}{\text{V.i. 1934–8}}$ average	98	104	97	86	86	50	47	50	..

V.i. = volume increment.

Regression calculations showed that 71 per cent. of the total variation in basal area was due to the varying number of whorls.

It appears that the removal of one whorl from below already seems to have reduced basal area increment.

The volume increment ratios given in the last line of the table were calculated by Ladefoged from form factors taken from a Danish curve with the total height of the tree as the sole determinant and therefore cannot be considered as more than a rough approach, being possibly strongly influenced by irrelevant height variations.

The measurements at 1·3, 3·3, and 5·3 m. above ground showed, in accordance with the results of Lehtpere, Hartig, and others, that diameter growth was most influenced by pruning at breast height. With a reduction in the number of live whorls from 12 to 5 there followed a reduction in annual basal area increment which, at 1·3 m., amounted to 80 per cent., at 3·3 m. 65 per cent., and at 5·3 m. only 45 per cent.

The first whorls removed seem to have positively influenced basal area increment at 5·3 m. and to have had little influence at 3·3 and 1·3 m.

Ladefoged also analysed the crown structure, and gives for the single whorls

values for length of branches, light conditions, needle weight, and content of chlorophyll, &c.

As a mean of six trees examined at the start of the experiment he found the following figures:

Height, 9·75 m.; diameter, 10·4 cm.; crown ratio, 0·66.

Although the lower branches were the longest (the lowest though a little shorter than the next), they evidently play a very modest part in dry matter production.

TABLE X. *Dry weight of needles (Ladefoged) and probable contribution (Møller)*

Number of whorls from the top	*Dry weight of needles*		*Probable contribution to stem increment* (%)
	(*g.*)	(%)	
1	34	1	2
2	138	3	5
3	346	8	12
4	654	15	17
5	743	18	18
6	756	18	18
7	574	14	13
8	518	12	10
9	320	8	5
10	136	3	0
11	(10)	..	..
	4,229	100	100

(The last column has been calculated by the author, see later.)

Since the chlorophyll content in per cent. of dry weight falls by more than 50 per cent. from the top downward, and from the outermost annual shoots inward, and since light conditions naturally showed the same tendency, the importance of the lower whorls with regard to increment is even smaller than seems at first look, although it must be remembered that CO_2 assimilation does not fall in proportion to the illumination but much slower.

Considering the inevitable respiration loss in the lowest whorls (nos. 10 and 11) in relation to their small needle weight it seems natural to suppose that their contributions to stem increment are zero or even negative. Though it seems hardly likely that carbohydrates and the like move outward in the phloëm, these branches in all cases receive water and mineral nutrients which, during the last year or two of the whorl's life, must be considered lost to the stem.

On the basis of Stålfelt's (1924) assimilation curves, Ladefoged has calculated that half of the total assimilation in tree crowns with nine to eleven live whorls takes place in the uppermost four or five whorls.

In a similar way and assuming that the tenth whorl's contribution to stem increment is zero, the author arrived at the figures given in the last column of Table X; these should provide an approximate value for the probable immediate reduction in stem increment by removing tenths of the live crown from below in young coniferous stands with a crown ratio of about 0·6.

CONCLUSIONS

1. The commonly accepted maxim that one-third of the length of the live crown can be removed without reducing increment is not correct.

2. Most experiments have shown a depressing effect on growth although comparisons have almost always been made on the basis of increments calculated as means of several years after pruning.

3. In the two cases where pruning of 25 per cent. of the live crown gave greater increment than no pruning (Stein) or where pruning of up to one-third of the live crown had no significant effect (Weck), it can be shown that either the conclusion was not justified, or that the result obtained, because of the use of means over a very long period after pruning, did not exclude a depressing effect during the first years after pruning.

Kienitz's belief that green pruning primarily promotes the increment of the leading trees is not supported by his own figures.

4. The order of magnitude of the depressing effect that may be expected as an immediate result of pruning from below is expressed by the figures in the last column of Table X; these have been estimated on the basis of Ladefoged's measurements of the dry weight of needles in the single whorls of a young stand of Norway spruce combined with a detailed study of chlorophyll contents and illumination of the different annual shoots in the single whorls.

According to the general impression obtained from the literature it is assumed that the figures for Norway spruce may also be valid for other conifers.

5. During the first growing season the depressing effect will already be slightly diminished by the formation of a new top whorl, and when as many new top whorls have been formed as correspond to the number of whorls removed from below, the depressing effect will almost vanish. As a rule this effect will not totally disappear at that time, since through normal development and thinning the length of the live crown gradually increases, although the crown ratio normally falls during the first decades after thinning has started.

6. One live whorl removed every year will mean a small annual strengthening of the pruning effect on increment. As a rule it will reduce the live-crown length, since height growth falls off with age, but even if the live crown is not shortened, the crown ratio will be reduced.

7. Pruning of a certain percentage of the live crown from below will naturally be the more quickly compensated the younger the stand, firstly, because, for example, one-third of the live crown means fewer whorls in a young stand than in an old one, and secondly, because height increment gradually falls off with age.

8. Pruning from below tends to improve the form of the clear bole, since diameter increment diminishes less immediately below the live crown than at breast height, or does not diminish at all (Hartig, Ladefoged, Lehtpere, *et al.*).

9. The depressing effect on increment of a *single* moderate pruning in a young stand, because of the rapid increase in volume of the single stem, will only represent a small part of the total volume production, having been produced by the old stand. When only few of the young stems are pruned, the fraction will be insignificant.

If, as in Lehtpere's experiment, a single pruning of 33 per cent. of the live-crown length in a young stand of Douglas fir means a reduction of about 20 per cent. of 2 years' increment, then according to the yield tables, with all trees pruned, this will give a reduction in the stand's total production up to 60 years of about 0·6 per cent., and with only one-sixth pruned, of about 0·1 per cent.

10. Height increment is influenced considerably less by heavy pruning than diameter increment at breast height. When only one-third of the live crown was removed, there was no significant effect on height growth (Lehtpere *et al.*).

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APPLICATION OF FERTILIZERS TO CHECKED PLANTATIONS

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SUMMARY

In April 1959 an aircraft was used for the first time in Britain to broadcast fertilizers on to an existing forest crop. This operation was the culmination of investigations over the previous 8 years into the causes of slow growth of spruce plantations (*Picea* spp.) over appreciable areas of soils derived from Culm Measures, notably at Wilsey Down forest, Cornwall, and Halwill forest, Devon. At these sites, many plantations dating from the early 1930's are almost completely 'checked', having failed to close canopy in up to 30 years. Recent experiments have suggested that nutrient deficiencies are largely responsible for the failure, and in 1957–9 the trials were extended to include exercises in the use of tractor-mounted equipment and aircraft for spreading fertilizers on a practical forest scale. The paper provides a short review of the site problems and experiment results at Wilsey Down, together with an account of the larger-scale fertilizer-spreading operations.

THE NATURE OF THE PROBLEM AREAS

Site characteristics. Wilsey Down is an exposed heath within 7 miles of the Atlantic, most of the forest exceeding 800 feet above sea-level being fully exposed to the prevailing winds. The climate is oceanic, the dominant features being a high rainfall (mean 55 inches per annum), and frequent strong winds.

The soil, which is a remarkably uniform gleyed podsol, is derived from Lower Culm Measures. Characteristically the profile consists of a shallow A horizon of 6–10 inches of dark peaty loam (pH 4·0), separated by a well-marked stoney layer from a gleyed B horizon consisting of a green-grey, compact, structureless clay-loam with frequent shale stones. Vertical drainage is impeded, and after heavy rain most of the natural drainage is lateral on the generally gently sloping ground. In common with most Culm soils, bases are low, and phosphate levels are very low. Recent analyses show total phosphate levels ranging from 290 parts per million total Phosphorus in the A horizon to 250 p.p.m. total P in the lower B and C horizons. These levels are low by any standards, and there is evidence that tree growth may be adversely affected at phosphate levels below 550–600 p.p.m. P in the B and C horizons (Green and Wood, 1957).

Vegetation consists of an association of *Calluna*, *Molinia*, and *Ulex gallii*, with less frequent occurrence of *U. europaeus*, *Erica cinerea*, and *E. tetralix*. *Scirpus* occurs in the worst drained areas, and *Agrostis setacea* becomes a major component on well-drained plough ridges. Generally, the vegetation is dominated by varying proportions of the first three species which form a dense mat 6–12 inches thick.

Tree species and afforestation methods. Planting began in 1928, and most of the area was completed by 1934. Sitka spruce (*Picea sitchensis* Carr.) was the main species used, and with the exception of a few scattered areas of fair growth, the crops are now all in a moribund condition. Small areas of other species were also planted in this period, and now show very variable growth. Japanese larch (*Larix*

leptolepis Gord.) and Norway spruce (*Picea abies* Karst.) are no better than Sitka spruce, but Lawson cypress (*Chamaecyparis lawsoniana* Parl.) planted in two small pure blocks in 1938 has grown reasonably well. *Pinus contorta* Loud. which was planted in mixture with spruce and in beating-up of failures, is also poor, largely owing to the unfortunate use of an 'Inland' strain for most of the planting. The few groups of 'Coastal' strain *P. contorta* occurring are vigorous and healthy, and are clearly the best adapted of any species tried on this difficult site.

In the early years planting was done directly into a screefed patch or inverted turf without preparatory cultivation or manuring. The early complete failure of these plantations led, in 1932, to the use of basic slag dressings to turf-planted trees. It was soon apparent that this was no lasting remedy, as despite an early growth improvement the trees became checked within 3–4 years of planting. Attention was then turned to providing better preparatory cultivation for improved drainage and vegetation suppression, and from 1932 onwards an 'Oliver' plough was used to cultivate strips, 9 inches deep, before planting. Unfortunately, the ensuing growth was little better than that following turf planting.

Planting was completed in 1939, but towards the end of the war it became obvious that a large proportion of the plantations were doomed to remain in check unless some rehabilitation treatments were applied. At the same time, in other heathland areas of the country, striking successes were being achieved in establishing plantations on ground prepared by deep, 12–18 inches, single-furrow ploughing. Accordingly, in 1944 one of the new R.L.R. heavy ploughs was brought in, and a small part of the checked area was ploughed giving single furrows 18 inches deep and 5 feet apart, and replanted with Sitka spruce on the plough ridges. This resulted in a considerable improvement of early growth, but by 1949 the deep ploughed area had also subsided into a state of growth check.

The nature of the crop failure and the possible causes. In the summer of 1951 the Research Branch of the Forestry Commission was asked to investigate the problem to determine the causes of crop failure and indicate methods of improvement. Detailed examination of the area by the Commission's Ecologist, Mr. J. M. B. Brown, showed that although most of the area under spruce was in a state of check, there were numerous small patches of better growth which could provide clues to the causes of growth variations (Brown, 1951).

The checked areas, which comprise about 90 per cent. of the forest are mostly made up of trees 2 to 6 feet high at 25–30 years old. Typically, many of the trees show dead tips and repeated shoot die-back associated with a sudden wilting of the young developing shoots in the early summer. Most of these trees are completely moribund, the small annual shoot growth being offset by the repeated wilt and die-back of shoots. Root systems are very extensive, and 2–3 feet trees commonly have roots spreading over an area of 15–20 feet radius. However, rooting is very shallow, and is almost entirely confined to the upper 3–4 inches of the A horizon. Scattered patches of better growth occur over the area (see Fig. 1). In some of these patches the trees have closed canopy at 15–25 feet, the best groups corresponding approximately to quality class IV. The areas of better growth can be classified as follows:

1. Fringes at the forest edge (notably Compartments 5 and 9 to the south, and Compartment 12 to the north-west—see Fig. 1). Here, soils are not markedly different from elsewhere, but there are signs that there was less *calluna* in the vegetation at the time of planting. Also, it could be that better growth is associated with the manuring effect of previous gathering of cattle at these old boundaries, or improved water supplies associated with the concave slopes.

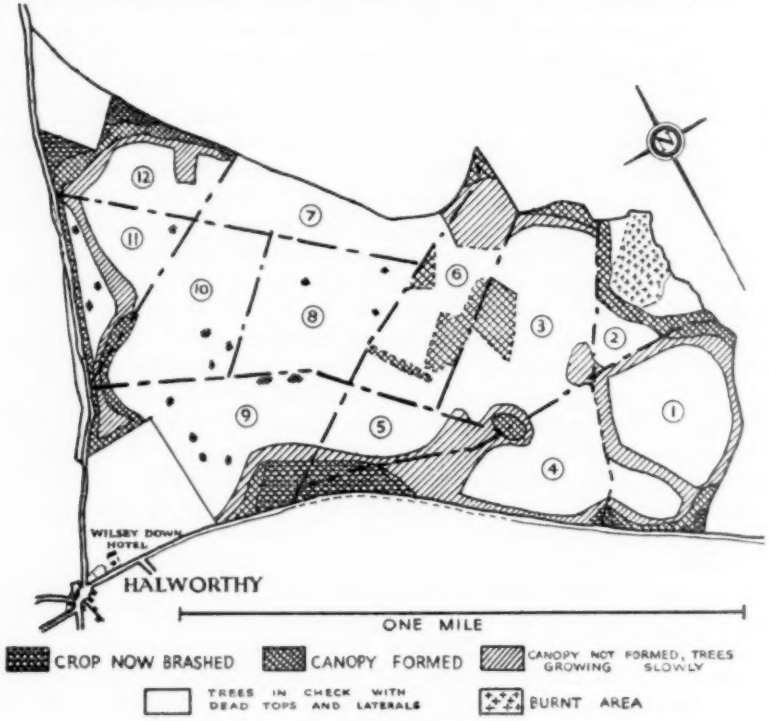

Fig. 1. Wilsey Down.

2. Fringes of internal rides. There are numerous instances of better growth where ride trimmings and soil from ride-side ditches were deposited around the outside rows of trees.

3. Tumuli. Clumps of better growth commonly occur in the immediate vicinity of tumuli present over the area.

4. Spring lines. Strips of better growth along spring drainage lines and flushes.

5. Scattered clumps. Small, up to 10 yards diameter, clumps of better growth, scattered in a manner unrelated to topography and exposure. In many instances there is clear evidence of shallow excavations at the centre of each clump, suggesting that soil disturbance may be important. Several observers have suggested that these clumps mark the sites of old mineral workings, or possibly peat stacks.

The presence of these areas of better growth suggests that exposure and the general climatic conditions are not in themselves limiting to growth. The problem appears to be basically one of site, particularly the factors of water and nutrient supply. Despite the high rainfall, spring and summer droughts are common. Also, drainage is undoubtedly defective, so that a major problem is how to dispose of excessive soil water in the winter without running the risk of drought in dry summers. In this connexion, deep single-furrow ploughing, especially on sloping ground, may be criticized as a treatment likely to accentuate summer drought effects. However, there is no clear evidence that water is limiting, and existing growth variations cannot be definitely related to water supply. The site is impoverished, and the evidence of better growth associated with former cattle standings, spring drainage lines, and areas of soil disturbance, suggests that faulty nutrition, through soil deficiencies and difficulty of rooting in the compact soil, is basically the cause of the trouble. In addition, the existing heavy mat of vegetation is almost certainly exerting an effect by competition for nutrient and water supplies. It is noteworthy that the shallow rooting habit of the spruce brings it in immediate competition with the surface root systems of *calluna* and *molinia*.

Following these preliminary observations, a series of forest experiments was started in 1952–3 to examine the possibilities of improving the crops by adding nutrients.

THE RESULTS OF FIELD EXPERIMENTS

According to crop records, manuring with basic slag was done on a trial basis from 1931 onwards. Unfortunately, details of dosage rates are not available and in the few cases recorded the effects of slag on crop growth were small and transitory. However, in view of the evidence of nutrient deficiencies on the site it was decided to proceed with fertilizer trials in 1953 (Wood and Holmes, 1957).

Placed dressings of nitrogen (N), *phosphorus* (P), *and potassium* (K) (NPK). The first trial was laid down in 1953 in a checked crop of Sitka spruce planted in 1934, which had been deep ploughed by R.L.R. in 1948 between the rows of trees, and replanted with spruce in 1950. Thus, at the time of fertilizer dressings in 1953, two ages of crop were present, both of which were in check. The treatments applied in 1953 were as follows:

(i) NPK applied as a placed dressing to the *1934 trees only* at 2 oz. hoof and horn, 2 oz. bonemeal, and 1 oz. muriate of potash per tree (i.e. approximately 31 lb. N, 20 lb. P, and 56 lb. K per acre).

(ii) Broom (*Sarothamnus scoparius*) sown as a nitrogen-nodule forming nurse species between each plant position. It was essential to manure the broom sowing positions to ensure survival and growth, so each position received 2 oz. bonemeal before sowing (i.e. approximately 20 lb. P. per acre).

Results to the end of 1956 are summarized below.

NPK as a placed dressing resulted in considerable growth increase both in the 1934 and 1950 plantings. Owing to the widespread shallow root system of the trees, fertilizer placement appears to have little significance, and it seems that fertilizers concentrated in any position are likely to influence growth of several

trees within root range. The growth was also improved in broom and bonemeal plots, and the greatest response appeared in the combined NPK and broom and bonemeal treatment. The effect of broom as such cannot be separated from that of the associated bonemeal dressing in this experiment, but in view of the early response of the trees it is likely that the increased growth is largely attributable to the bonemeal.

TABLE I. *Summary of height growth responses of Sitka spruce to NPK dressings and broom sowings*

Treatments (i) *Fertilizer to 1934 spruce* (ii) *Broom+bonemeal*	*Initial height 1953 (ft.)*	*Height increase (ft.) 1954–6*			
		O	*NPK*	*O*	*NPK*
		O	*O*	*Broom+P*	*Broom+P*
(i) Sitka spruce (planted 1934)	2·5	0·18	0·70	0·99	1·28
(ii) Sitka spruce (planted 1950)	1·9	0·26	1·18	1·13	1·67

TABLE II. *Sitka spruce. Height growth and incidence of shoot 'wilt' in relation to broadcast PK dressings*

PK treatment (*lb. element and (cwt. compound) per acre*)	*1954 height (ft.)*	*1958 height (ft.)*	*Height increase 1954–8 (ft.)*	*Total increase as % of 1954 height (%)*	*% trees with shoot 'wilt' 1958*
1934 Spruce					
0	3·36	3·0	0	0	90+
15 lb. P+30 lb. K (2 cwt.)	2·87	4·78	1·91	66	24
45 „ 90 „ (6 „)	2·86	6·31	3·45	121	0
90 „ 180 „ (12 „)	2·91	7·88	4·97	171	0
1950 Spruce					
0	2·08	2·46	0·38	18	90+
15 lb. P+30 lb. K (2 cwt.)	1·96	4·57	2·61	133	30
45 „ 90 „ (6 „)	1·84	6·44	4·60	250	2
90 „ 180 „ (12 „)	1·91	7·72	5·81	304	0

Broadcast Dressings of PK. Following the first encouraging results, larger plots were treated in 1954 testing dosage rates of PK granular compound fertilizer, (0:16:16), *broadcast* along the 1948 plough ridges. Treatments were applied in the summer of 1954 at 2, 6, and 12 cwt. per acre (gross), (i.e. approximately 15 lb. P+30 lb. K, 45 lb. P+90 lb. K, and 90 lb. P+180 lb. K, per acre, respectively). The growth increases achieved to the end of 1958 are summarized in Table II, together with a note of the percentage of trees affected by the shoot 'wilt' and dieback symptoms, described earlier (page 55). Growth responses were very striking, especially in view of the fact that it had been reported earlier that the 1934 crop received basic slag at planting and failed to show any marked response. Unmanured trees showed insignificant growth from 1954 to 1958, while in the same period trees which received 6 cwt. 0:16:16:PK (45 lb. P+90 lb. K) per

acre, developed to the stage of closing canopy and suppressing the dense natural vegetation. There was a notable difference in the response of the two ages of crop. The younger crop, situated on the 1948 R.L.R. plough ridges, was the more responsive, which is probably associated with the fact that dressings were concentrated along the ridges where the roots of this crop are located.

Manuring has also greatly increased the depth of rooting of the crop. Treated trees now have large numbers of roots penetrating into the hard C horizon under conditions where the roots of control trees are confined to the top 3–4 inches of soil.

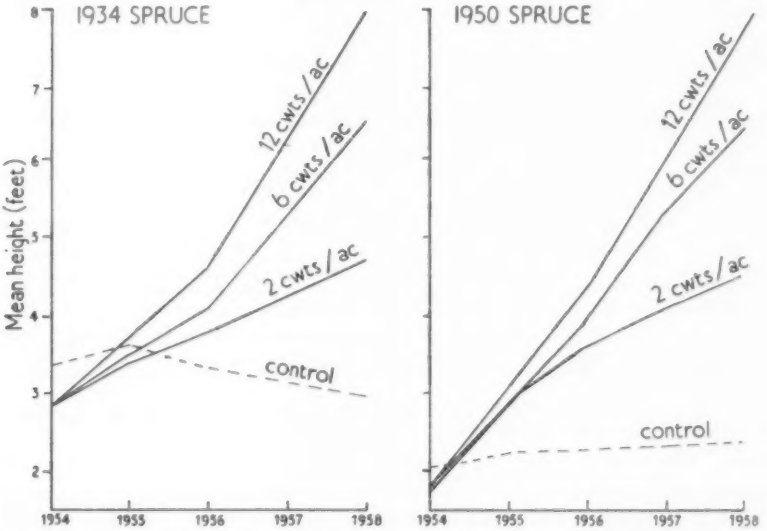

FIG. 2. Sitka spruce. Height growth of trees planted 1934 and 1950 as affected by dosage rate of PK fertilizer applied 1954.

Despite the dramatic growth improvements it is always possible that the trees may revert to a checked condition in time. It seems unlikely that this will happen providing vigorous growth can be maintained long enough for the crop to close canopy and dominate the site. At the lowest dosage rate, there are already signs of a reversion to a checked condition as exemplified by the extent of shoot wilting and dieback in 1958 (see Table II). Trees receiving 15 lb. P+30 lb. K per acre had 24–30 per cent. of trees exhibiting wilt and dieback in 1958, compared with negligible dieback in trees receiving 45 lb. P+90 lb. K per acre or more. Height measurements over the period of the experiment show no sign of a decline in vigour except at the lowest dosage in the 1950 crop (see Fig. 2). At first it was thought that the thick mat of natural vegetation would seriously limit the uptake of broadcast fertilizer dressings by the crop, but this was found not to be the case. The vegetation has responded to manures, especially *Ulex*, but not nearly so markedly as anticipated.

Separation of P and K effects. From the above results it was not possible to assess the relative importance of P and K, also as the results were obtained on a deeply ploughed site, the conclusions could not be applied to the large area of checked crops on unploughed ground. Accordingly, in 1956 a factorial P × K experiment was established on ploughed and unploughed ground to test the separate and combined effects of broadcast dressings of these elements. The rates applied were as follows:

P = 15 lb. P per acre as superphosphate
PP = 30 lb. P „ „
K = 30 lb. K „ sulphate of potash
KK = 60 lb. K „ „

The results to the end of 1957 are summarized in Table III.

TABLE III. *Sitka spruce (1934). Height growth and incidence of shoot wilt symptoms in relation to dosage rates of P and K*

	O		*P*		*PP*			
Treatments	*1957 height (ft.)*	*% trees wilted*	*1957 height (ft.)*	*% trees wilted*	*1957 height (ft.)*	*% trees wilted*	*S.E. (HTS)*	*Differences for significance (HTS)*
O	2·87	65	3·57	4	4·08	0	0·15	5% = 0·44
K	3·00	68	3·76	3	4·10	0		1% = 0·60
KK	..	..	3·76	4	4·03	0		..

Both in the presence and absence of K, phosphate gave a highly significant height increase, and 30 lb. P ('PP') was significantly better than the 15 lb. P ('P') rate. There was no significant effect of K applied alone or in combination with phosphate. The table also clearly illustrates the effect of phosphate in clearing up shoot wilt symptoms, no wilt being present on trees receiving 30 lb. P per acre. Results were similar both on ploughed and unploughed ground, and serve to confirm previous indications that phosphate is the main immediate requirement for growth and removal of wilt and dieback symptoms.

Triple superphosphate as broadcast and placed dressings. Before large-scale applications of phosphate were considered, it was decided to carry out tests of methods of placement and dosage rates with a more concentrated phosphate fertilizer, better suited for large-scale use than the forms tested hitherto. Triple superphosphate was an obvious choice, being granular and easy to apply, and concentrated (20 per cent. P), and therefore economical in bulk. Trial applications of triple superphosphate were made in 1957 at 0·7 cwt. (15 lb. P), 2·0 cwt. (45 lb. P), and 6·0 cwt. (135 lb. P) per acre, applied broadcast or placed in spots 10–12 feet apart throughout the treated area. Effects at the end of 1958 showed up markedly in favour of broadcast treatment in terms of the rapidity and scale of crop growth responses to any given rate. These treatments must be observed over several years before final conclusions can be made, but judging on short term effects triple-superphosphate applied broadcast appears a safe, effective, and practicable treatment.

Yellowing of shoots associated with phosphate dressings. Towards the end of 1958 unexpected abnormalities appeared in trees which had received certain phosphate treatments. It was noted that current shoots of trees in several phosphate plots had developed pronounced yellow-tips as a result of needle discoloration. The main features of affected trees can be summarized thus:

(i) Only current shoots were affected.
(ii) The whole shoot tapered towards the tip, the needles at the tip being much shorter than those at the base.
(iii) Needles were yellowish-green, the intensity of yellowing increasing towards the tip.
(iv) In severe cases, the needles at the tip had died back, preceded by a change of colour from yellow to mauve and then light brown.
(v) Terminal and secondary buds on all affected shoots appeared normal and healthy. Also, the shoots themselves were thick and vigorous.

It was observed that 'Yellow-tips' appeared at several sites simultaneously in 1958, including crops in the nearby forests of Halwill and Hartland as well as Wilsey Down. However, all sites had certain characteristics in common, viz.

(i) 'Yellow-tips' were confined to Sitka spruce crops which had received phosphate dressings for the relief of growth check.
(ii) All the affected crops were located on Culm soils and all had received phosphate in 1957.
(iii) All affected trees had received fairly heavy dressings of superphosphate or triple superphosphate at rates of *45 lb. P per acre or more.* At lower rates, i.e. 15–20 lb. P per acre, *no* shoot yellowing was apparent.

The 1957 dressings were the first in which phosphate was applied alone at rates as high as 45 lb. P per acre, and they were the only dressings which gave rise to yellow-tip symptoms. In the 1954 P and K factorial experiment the heaviest rate was 30 lb. P per acre. The 1953 broadcast trial (see Table I) included rates of 45 lb. and 90 lb. P per acre, but these were combined with heavy rates of potash. The absence of 'yellow-tips' following heavy dressings of PK in the latter trial could be interpreted as an indication that potash is necessary to avoid an 'induced' deficiency when heavy rates of phosphate are applied. The general symptoms were strongly suggestive of potash or magnesium deficiencies in other crops. Fortunately, whatever the explanation, the symptoms appear quite transitory and in 1959, all the buds on affected shoots developed normally, producing vigorous and healthy coloured shoots.

Current experiments. Recent experiments include studies of the influence of minor elements, including zinc, copper, boron, and molybdenum on the incidence of shoot wilt and dieback, and tests of these elements with the addition of nitrogen, potash, and magnesium as diagnostic treatments to trees likely to be affected by the 'Yellow-tip' symptoms described. No effects of these treatments are apparent at the present time.

Conclusions. The results of experiments to date can be briefly summed-up as follows:

(i) If no remedial treatments are applied the spruce crops will remain in check more or less indefinitely.

(ii) Phosphate additions result in disappearance of shoot-wilt and dieback symptoms and a vigorous resumption of growth. These effects persist at least until the crop closes canopy, providing the application rates exceed about 45 lb. P per acre.

(iii) Broadcast dressings appear to be more efficient, giving quicker and larger initial growth increases than placed dressings.

(iv) There appear to be no important differences in effect between forms of phosphate, i.e. bonemeal, superphosphate, and triple superphosphate, equated in terms of P.

(v) Potash additions have had no measurable effect on growth, either alone or in the presence of phosphate.

(vi) An unexplained shoot 'Yellow-tip' symptom appears to be associated with phosphate applied *alone* at rates exceeding about 45 lb. P per acre. This symptom appeared the year following treatment, and seems to disappear completely in the subsequent year.

On the basis of these conclusions it was decided to proceed with practical scale dressings in 1957 using triple-superphosphate at 3 cwt. (= 67 lb. P) per acre. Experiment results indicate that this treatment is likely to be effective, and will certainly be much cheaper than the alternative of whole or partial reploughing, manuring, and replanting of the checked areas.

TRIALS OF MECHANICAL METHODS OF FERTILIZER SPREADING.

There is very little experience available in Britain on methods of broadcast fertilizer application to forest crops on a practical scale. In the past, fertilizer applications have been largely confined to placed dressings of phosphate applied by hand to individual trees shortly after planting. In these circumstances, hand applications are quite practical, but in established crops where broadcast distribution is preferable, spreading by hand is likely to be expensive and inefficient. The difficulty of uniform spreading and physical difficulties of progress through the crop and vegetation as well as high labour costs, mitigate against broadcasting by hand, and mechanized spreading seems the only practical solution.

(*a*) *Trials of ground equipment in 1957*

Experience on the Continent with several types of tractor mounted or drawn fertilizer spreaders and blowers, has shown that ground equipment can be used efficiently and cheaply under some conditions (Van Broekhuizen (5)). However, in many areas steep and broken ground and the obstacle of the crop itself set definite limits to the circumstances in which wheeled or tracked equipment can operate. Checked crops of the type in question present no serious obstacle to a tractor, and in 1957 preliminary trials were carried out over a 10-acre block at Wilsey Down using a 'spinner' type fertilizer spreader.

Massey-Harris-Ferguson provided a tractor mounted spinner-distributor developed for fertilizer spreading over rough ground where conventional drills could not be used. The main features of the machine are shown in Fig. 3. Basically, the distributor consists of a hopper (capacity 4 cwt. granular fertilizer) fitted with an agitator and adjustable delivery vent through which the fertilizer falls on to a spinning disk which spreads the material in a wide arc at the rear of the machine. Application rates can be adjusted from ½ to 40 cwt. per acre by means of

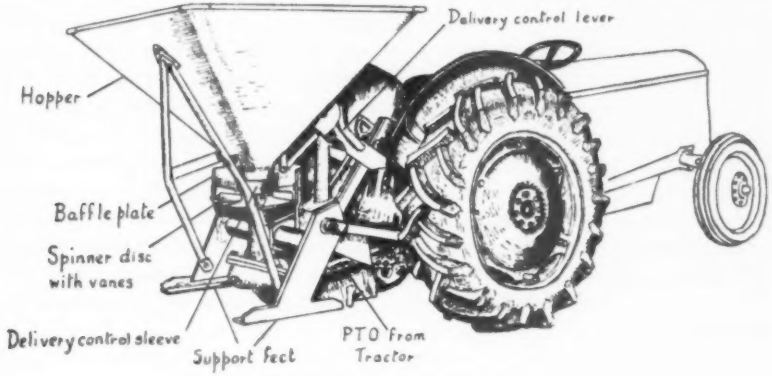

FIG. 3. Tractor mounted spinner-distributor.

a thumb screw on the delivery control lever. The whole unit is mounted on the tractor hydraulic linkage and powered from the P.T.O. (power-take-off) shaft. For the trial the spinner was mounted on a Fordson Major tractor fitted with double rear wheels to provide adequate traction through the heavy vegetation cover.

A 10-acre block of checked spruce was divided into several plots for application of triple superphosphate at 3 cwt. (67 lb. P) and 6 cwt. (135 lb. P) per acre. Several preliminary 'dummy' runs were carried out for purposes of calibration, and during the course of these it was found that the machine was capable of spreading material over a swath width of 20 feet irrespective of land speed and delivery setting. Accordingly, the trial plots were treated in 20-foot swathes, the tractor being guided between the rows of trees as follows:

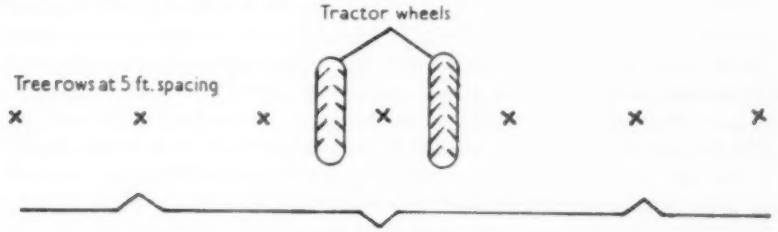

FIG. 4

The tractor traversed the area remarkably well considering the rough conditions, but a fully tracked machine would have been preferable for the task. Surprisingly little damage was done to the tree crop by the passage of the tractor. Most of the trees flattened beneath the belly of the tractor, sprang upright immediately, the only apparent injury being to trees over 3 feet high which suffered some bark stripping from the bumper bar at the front of the machine. Following initial difficulties in calibration, the spinner worked satisfactorily, giving a reasonably uniform spread of material over each 20-foot swath. Measurements of the amounts of fertilizer applied to each plot showed that the control of rates was very satisfactory. Thus, at the '3 cwt.' rate, the amount applied ranged from 2·8 to 3·2 cwt. per acre, and at the '6 cwt.' rate ranged from 6·0 to 6·3 cwt. per acre.

Some trouble was encountered owing to stoppages caused by occasional large-size fertilizer granules and pieces of fertilizer bags which clogged the hopper outlet. This problem could be readily surmounted by use of a wire mesh to screen the fertilizer at the time the hopper is filled. In addition the spinner disk was mounted only about 2 feet above ground-level and the throw of fertilizers was upset by trees 2 feet or more in height. Similarly, the supporting feet of the distributor were only about 9 inches above ground-level and were a constant source of trouble as they repeatedly fouled the ground and vegetation. These difficulties could be overcome by

1. Higher mounting of the machine.
2. Attachment of the supporting feet by means of bolts so that they can be removed if necessary.
3. 'Dish' the spinner disk to give a higher throw of fertilizer to clear tree growth and vegetation.

Subject to these modifications a spinner-type spreader can be useful under forest conditions, although its scope is limited to relatively easy ground and crops less than 2–3 feet high. Discounting stoppages due to inexperience during the trials, the machine was capable of covering about 2 acres per hour, which with machine and additional labour charges would amount to an application cost of the order of 15*s*. per acre.

(*b*) *Trials of aerial spreading methods in 1959*

In general, aircraft are characterized by a large rate of work and relatively high operating costs. Thus, aircraft can topdress 200 to 400 acres per day compared with 20 to 40 acres per day for ground equipment, but despite this difference, aircraft cost more per acre and their use can be justified only in circumstances where mechanized ground methods cannot be used (Saunders, —). Many forest areas fall into this category and operation of ground equipment is severely limited by the obstacles of difficult topography and the crop and vegetation cover. In such circumstances, aerial application seems the only practical answer.

In 1959 aerial dressings were applied to selected areas of Wilsey Down and Halwill forests with the object of gaining first hand experience of the techniques and organization involved. After preliminary discussion with the contractors it

was decided that two types of trial application should be made, viz. (i) a practical exercise applying the best indicated treatment to a large area, and (ii) application of a range of experimental treatments to small plots in thicket stage crops impenetrable for treatment other than from the air.

The aircraft used was a Tiger Moth operated by Crop Culture Ltd. (Bembridge). Although it is a small biplane, this machine has the great advantages of cheapness, stability in flying and applying fertilizers at relatively low speeds over rough country, and it requires a shorter take-off strip, i.e. about 350 yards minimum, compared with most types. The aeroplane provided was specially fitted out for fertilizer spreading, the front cockpit having been converted into a hopper with a capacity of 5 cwt. of granular material. Fertilizer delivery rates were controlled by means of a simple shutter and vent at the base of the hopper, the aperture of which could be adjusted and controlled from the cockpit. On leaving the outlet vent the fertilizer fell into a powerful draught of air within a metal scoop or venturi mounted outside the aircraft beneath the hopper. The draught force carried the fertilizer out through a pair of 'fish-tail' outlets, which spread the granules fanwise towards the tail of the aircraft. On leaving the machine the fertilizer is caught up in the slipstream, which further assists in spreading the material (see Plate).

The main additional item of special equipment was a high speed fertilizer loader consisting of a 5 cwt. capacity canvas hopper mounted on hydraulically controlled arms on the front of a vehicle. The hopper could be lowered for easy filling off a ramp or trailer, and when full could be raised and manœuvred into position for rapid dumping of the load into the stationary aircraft.

(i) *Practical scale applications.* Two adjacent blocks of checked spruce of approximately 65 and 20 acres each and one detached block of about 10 acres, were selected for aerial dressings with granular triple superphosphate at 3 cwt. per acre. The extent and position of the treated areas are shown in Fig. 5.

In most types of fertilizer spreading work the aircraft is operated at a speed of 60–70 m.p.h. at a height of 15–40 feet, depending on the nature of ground variations and crop cover. At Wilsey Down, where there were sharp irregularities in crop height, flights were generally made at 40 feet, which gave a spread of fertilizer over a swath width of about 36 feet per flight. Thus, complete coverage of the area involved flying a series of parallel flight lines, 36 feet apart, over each block.

Personnel and organization. The personnel directly employed consisted of the pilot, the loading machine operator, two forest workers assisting in loading, and two foresters who acted as flight markers and supervisors of applications in the dropping area. An excellent landing strip was available on a disused aerodrome within 4 miles of the dropping area, and this was made the base of operations and the main dump and loading point for fertilizer materials.

In the dropping area applications were made in long swathes in the direction indicated in Fig. 5. The two flight markers, who were provided with white overalls and 15-foot aluminium poles carrying flags, were stationed on the rides at the north-west and south-east limits of the main Blocks 'A', and 'B'. On each flight

the aircraft was lined up on the two markers, the pilot opening the hopper outlet as he passed over the first marker into the dropping area. On completion of each swath, the markers moved to the next swath line, and the procedure was repeated.

During most of the operation the markers could not see each other because of the intervening crop or rising ground, so each was provided with a radio pack-set

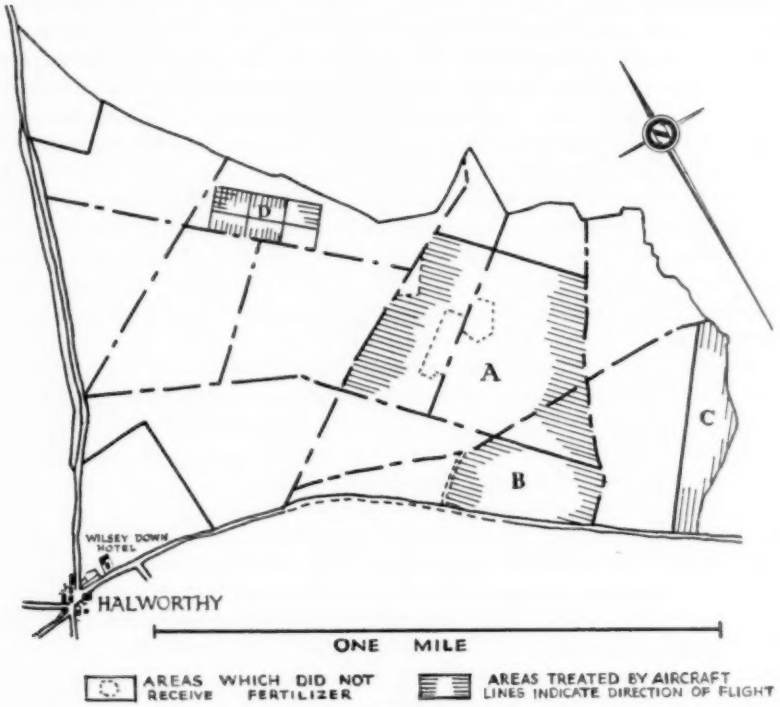

Fig. 5. Wilsey Down.

to enable them to communicate and synchronize their stationing and movement from one swath line to the next. Radio contact between markers was found to be quite essential in controlling their positioning in the short interval between the aircraft completing one swath and starting the next. The use of markers to indicate flight lines appears to be essential in controlling applications to large 'featureless' blocks of forest. Agricultural applications are frequently made without the aid of markers, but in these cases there are usually definite features visible on the ground to serve as guides to the pilot in locating swath lines. However, in small areas reasonable control can be achieved without markers as was demonstrated by the pilot who treated the whole of Block 'C' without the aid of markers. The use of human markers adds considerably to the cost of the operation, and the use of

marking devices dropped from the aircraft in flight is being investigated (Haronska, —).

At the loading point fertilizer bags were stacked on a flat-topped trailer, and emptied straight into the loading hopper, which could be lowered to the trailer level for the purpose. On the return of the unladen aircraft the loader was raised hydraulically and the fertilizer dropped into the aircraft hopper.

The organization of the operation was quite simple, and with a little practice it was possible to synchronize the movements of the aircraft, the markers, and the loading team, so that the work proceeded smoothly and without interruption.

Dosage rates and uniformity of application. The fertilizer hopper in the aircraft was fitted with a very positive 'on-off' control, which enabled the flow of fertilizer to be stopped and started with precision in flight. This feature made it possible to control the spreading sharply at the beginning and end of each swath, and to cut the flow when passing over wide rides and groups of large trees, as desired.

Before the main applications were started, a preliminary flight was made to calibrate the setting of the fertilizer outlet control. On the small test area treated at the selected setting, results agreed closely with the 3 cwt. per acre rate required, and the larger scale applications in Blocks 'A' and 'B' were completed at this setting. Unfortunately, the setting was later found to be too low, and the rates actually applied to these blocks were somewhat lower than intended, viz.:

	Block 'A'	*Block 'B'*
Net area treated . .	63·3 acres	17·7 acres
Fertilizer applied . .	155 cwt.	35 cwt.
Rate per acre . . .	*2·45 cwt.*	*2·0 cwt.*

Before treatment of Block 'C', which was flown without the aid of markers, the hopper setting was altered slightly and the final rate applied to this area of 11 acres was 4·25 cwt. per acre.

Closer attention should have been given to initial calibration of the hopper, and based on the experience of the first trial, subsequent dressings were controlled more accurately. However, application rate is not easy to control with precision as it can be so readily upset by variations in ground speed, overlapping or failure of swathes to meet in parallel, as well as variations in calibration of the delivery controls on the aircraft. Judged by eye, the spread of fertilizer appeared uniform over each 36-foot swath, although it could be seen that there was a tendency for the fertilizer to be concentrated at the inner edges of the two fish-tail outlets (see Plate). Appreciable quantities of fertilizer granules were intercepted by the crop and became lodged in the leaf axils. All the lodged material disappeared in a few days with no sign of injury or scorch of foliage. The rate of uniformity of application was measured by means of cone shaped muslin 'Powell' catchers placed on the ground. Catchers were placed at 15-foot intervals in a line at right angles to the flight lines, along the main ride intersecting Block 'A' (see Plate). Each

catcher had a collection area of 1 sq. ft. and weighing of the fertilizer retrieved gave the following results:

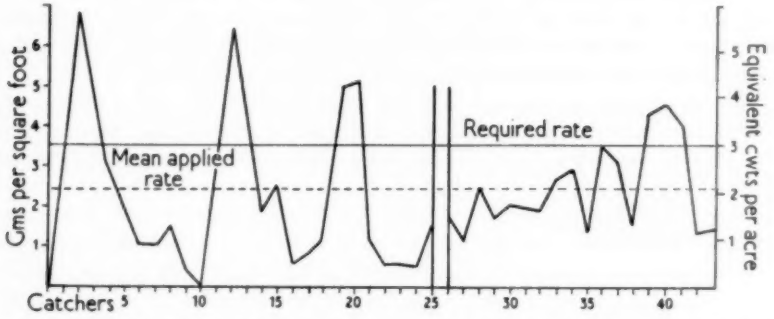

FIG. 6. Showing distribution of fertilizer, based on a single transect of 43 catchers placed at 5-yard intervals along the central ride dividing area A. (There is a gap of 217 yards between catchers 25 and 26 in which no catchers were placed.)

The overall average rate of 2·06 cwt. per acre confirms that the application was appreciably less than intended. Also, variations from catcher to catcher were considerable, particulary at the south end of the area.

These figures provide a measure of the variation in one direction only, *across* the swathes, and unfortunately it was not possible to measure variations along swathes. Until this can be done only an incomplete picture of the distribution pattern is available. The observed variations across the swathes seem to follow no set pattern and cannot be fully explained at this stage. The results achieved were not fully satisfactory, and the problem seems to be mainly a question of the design of spreading equipment which will improve as techniques advance. In the meantime, only time will show the significance of the observed variations in terms of crop response.

Rate of work and costs. All flights were carefully logged at the loading point and dropping areas and these records provide several measures of the rate of work achieved.

In all cases the load was 5 cwt. and the actual dropping time at 60 m.p.h. averaged 25 seconds per load, which at the rate of about 2½ cwt. per acre, is equivalent to about 5 acres per minute. However, this is an academic figure as the dropping time on average was only about 5 per cent. of the total time required per load. The greatest part of the time was occupied in flying to and from the dropping zone, so that the distance to the landing strip is of supreme importance in determining the rate of work. This fact is well shown, by comparing the flying times for Block 'C' with those of Blocks 'A' and 'B' in Table IV. Reduction of the flying distance by 1 mile (½ mile each way), increased the rate of work from 12–13 acres per hour to nearly 17 acres per hour.

For larger-scale work, using an airstrip no farther than 3 miles from the dropping area, it is estimated that the average rate of work should be 15–25 acres per

hour. With a larger aircraft having a larger pay-load, this could probably be increased to 25–35 acres per hour.

Costs. Actual operation costs of the aircraft are not available, but on a contract basis the final costs for 2½–3 cwt. fertilizer per acre were:

	per acre £ s. d.
Triple superphosphate at £2 per cwt.	5 0 0
Application	19 7
Total	£5 19 7

(ii) *Applications to experimental plots.* The aircraft was also used for application of a variety of experimental fertilizer treatments to small plots at Wilsey Down and Halwill forests. Two crops were treated, both being in the thicket stage of

TABLE IV. *Summary statement of areas treated and rates of work*

	Block 'A'	*Block 'B'*	*Block 'C'*
1. Area treated	63·3 acres	17·7 acres	11·1 acres
2. Distance from landing strip	3·5 miles	3·5 miles	3·0 miles
3. Average flying time per 5-cwt. load, i.e. take-off to landing	7·3 min.	7·7 min.	5·4 min.
4. Average dropping time per 5-cwt. load	25 sec.	25 sec.	25 sec.
5. Average turn-round and loading time, i.e. landing–loading–take-off*	1·8 min.	2·1 min.	1·8 min.
6. Total time per 5-cwt. load	9·1 min.	9·8 min.	7·2 min.
7. Average rate of work (acres per hour).	*13·2 acres*	*12·2 acres*	*16·7 acres*

* These figures include 9–10 minutes refuelling every 2½ hours. Excluding refuelling the turn-round time was 60 seconds.

development and quite impenetrable for treatment by hand or with ground equipment. These additional trials were valuable as they showed the versatility of the aircraft and the extent to which applications can be controlled under forest conditions, as well as providing informative experiments in crops inaccessible to treatment other than from the air.

The Wilsey Down experiment (area 'D' in Fig. 5) provided tests of nitrogen phosphorus and potassium dressings to a 1937 thicket stage mixture of *Pinus contorta* and Sitka spruce as follows:

P = phosphorus at 67 lb. P/acre as triple superphosphate at 3 cwt./acre.
PK = phosphorus+potash as PK compound at 2½ cwt./acre.
N = nitrogen at 103 lb. N/acre as pelletted Urea at 2 cwt./acre.

Treatments were broadcast with the aid of ground markers in a series of plots (Fig. 7). As previously, dressings were applied in 36-foot swathes, the P and PK plots being covered in 9 swathes in a north–south direction, and the N plots in 6 swathes in an east–west direction. All three fertilizers were granulated, but each had a different range of granule size and bulk density, which affected their rates of flow from

the hopper. Consequently, it was necessary to calibrate and set the hopper flow control independently for each material. The applications were entirely successful, the efficient 'on-off' control on the hopper enabling the drops to be accurately cut in and out even on swathes as short as 140 yards (i.e. north–south swathes). The rates actually applied were as follows:

Treatment	*Rate required per acre (cwt.)*	*Rate applied per acre (cwt.)*
Triple superphosphate .	3·0	3·3
PK compound . .	2·5	2·7
Pelletted Urea . .	2·0	2·0

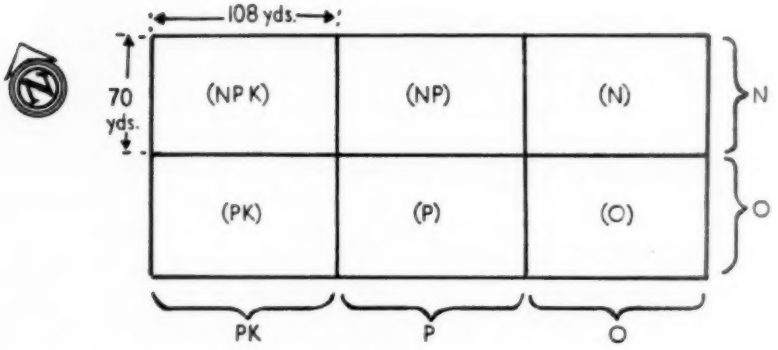

FIG. 7

As before the markers were in radio contact but it was not possible to contact the loading team by radio. In this case, owing to the risk of errors with three fertilizers, it was necessary to resort to a simple system of ground-to-air signals to advise the pilot which fertilizers should be loaded on the following flight.

A similar, but slightly more complex trial was carried out at Halwill forest in a poor quality thicket stage crop of Norway spruce planted in 1921. The soil conditions were similar to those at Wilsey Down except for drainage conditions. The object of the trial was assessment of the crop responses to fertilizer additions before large-scale dressings in the area are considered. Urea, triple superphosphate, and PK compound were applied as at Wilsey Down, except that the unit plots were much smaller, consisting of strips 24 yards (2 swathes) by 135 yards = approximately $\frac{3}{4}$ acre. Plots were arranged in 3 blocks of 5 plots (Fig. 8). At Halwill the landing strip was an agricultural field less than 2 miles away, and it was possible to establish radio contact between the senior marker and the loading team, as well as between markers. This greatly simplified the control of application and prevention of errors.

To facilitate accurate estimates of the amounts applied, the load per flight was limited to slightly more than the amount required per plot. Each plot was

treated in 2 swathes of 36 feet, all treatments being completed in 5 flights per block:

Flight 1. Triple superphosphate to Plot 'P'.
„ 2. PK compound to Plot 'PK'.
„ 3. PK compound to Plot 'NPK'.
„ 4. Urea to Plot 'N'.
„ 5. Urea to Plot 'NPK'.

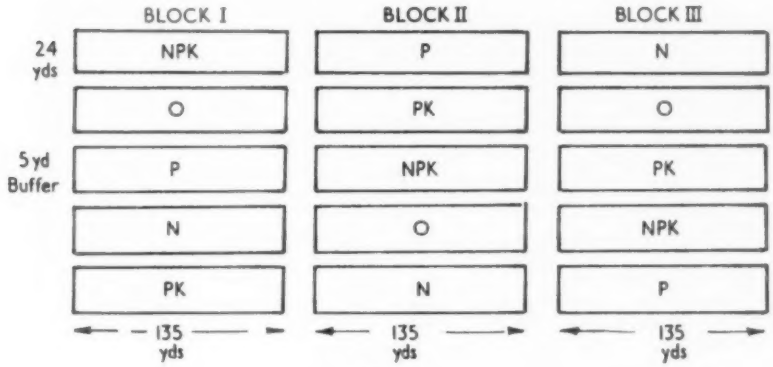

FIG. 8

The quantities actually applied were as follows:

TABLE V. *Halwill forest. Fertilizer application rates*

Treatment	*Rate required per acre (cwt.)*	*Rate applied per acre (cwt.)*			
		Block I	*Block II*	*Block III*	*Average*
Triple superphosphate . .	3·0	3·0	3·0	3·0	3·0
PK compound . . .	2·5	2·0	2·62	2·62	2·42
Urea	2·0	2·11	1·65	2·11	1·72

This was the last trial of the present series to be treated, and the improved control of application rates is probably a reflection of the experience of calibration gained in the earlier trials. It seems that with practice, application rates can be controlled to an acceptable standard of accuracy. Unfortunately, the same cannot be said for uniformity of distribution, and the results of weighing the catches from a line of fertilizer catchers placed *across* all plots in Block III are illustrated in Fig. 9 below. In examining this figure it is important to remember that the crop varied in height from 4 to 25 feet, and the varying proximity of larger trees to individual catchers will have affected the variations in the weights of fertilizer caught. As at Wilsey Down, the distribution was variable, also an appreciable amount of fertilizer was deposited over the plot boundaries, especially in the

case of N and P treatments. A fairly stiff and irregular breeze was blowing across the plots at the time of application, and on several occasions it was observed that there was appreciable drift of fertilizer downwind of the flight line. Attempts to correct this by flying slightly upwind of the marked flight lines showed an improvement, but were not always successful on account of the gustiness of the wind. In fact, the conditions were not suitable for accurate placement on plots as narrow as 24 yards.

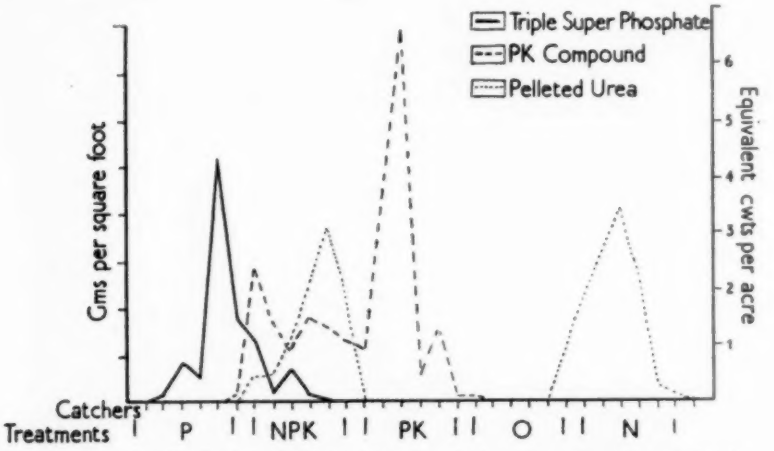

FIG. 9. Showing distribution of fertilizer based on a single transect of 30 catchers placed at 5-yard intervals.

(*c*) *Conclusions*

The main conclusions from the 1957 and 1959 application trials may be summarized as follows:

1. *Ground equipment.* Tractor-mounted equipment can provide a satisfactory method of uniform broadcasting but its use is restricted to easy ground, and where the crop presents no obstacle to the passage of the vehicle. Given these conditions a spinner-type distributor can be used cheaply and effectively with small modifications.

2. *Aerial dressings.*

(i) Trial dressings with a light aircraft were most promising indicating that the technique could be used over a wide range of forest conditions as the need arises.

(ii) Practical scale dressings of granular fertilizer at 2–3 cwt. per acre showed that a rate of 15–25 acres per hour can be achieved providing the airstrip lies within 3 miles of the dropping zone. Distance from the airstrip was a critical factor, efficiency falling off sharply as the distance is increased over 3 miles.

(iii) Control of application rates was satisfactory in the final trials. In the first

Close up showing pattern of distribution of fertilizer granules emerging from the venturi type spreading equipment. Note concentration of fertilizer on the side of the vents nearest the fuselage.

Pelletted urea granules intercepted by Norway spruce foliage at Halwill Forest after aerial application, 1959.

PLATE IV

Typical pattern of distribution of pelletted urea granules as shown in close up of a patch of bare soil (Halwill, 1959).

Assessment of fertilizer distribution and application rate. General view of line of catchers spaced at five yard intervals set out at right angles to the flight direction (Wilsey Down, 1959).

PLATE V

dressings there was difficulty in correct calibration of the delivery control, but with experience there seems no doubt that rates can be controlled to an acceptable level of accuracy.

(iv) Uniformity of spreading was not fully satisfactory. The precise causes of irregularities across the swathes are not known, but there is scope for improvement in the design of the spreading gear.

(v) Irregular topography appears to be no great obstacle with this method of fertilizing, and providing a landing strip of at least 350–400 yards is available a fixed wing machine seems the best type of aircraft for most forestry work.

(vi) Cost of application will vary with circumstances and scale of work, but it will be of the order of 20*s*. per 3 cwt. per acre.

The foregoing account describes the first results of trials of fertilizers and application methods under one restricted set of conditions, i.e. the infertile Culm soils of south-west England. Similar work is now proceeding on other soils in plantations ranging from checked crops to moderate quality pole-stage crops, in order to learn more of the nature of growth responses to fertilizer dressings under various conditions. Depending on the results obtained, aerial fertilizing could become an important practical proposition in forestry.

ACKNOWLEDGEMENTS

Thanks are due to Crop Culture Ltd., Imperial Chemical Industries Ltd., and Scottish Agricultural Industries Ltd., and to the Forestry Commission staff at Wilsey and Halwill forests for their ready co-operation and help in the recent trials. We are also indebted to Research Foresters D. Fourt and C. P. Kirkland who were responsible for much of the field experimental work at Wilsey Down from 1953 to 1956.

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FORESTRY IN YORKSHIRE

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(*Forestry Commission*)

SUMMARY

The history of Yorkshire's woodlands is briefly described, and the site factors influencing tree growth are considered in general terms. Problems concerning the economics and administration of the woodlands are discussed, and statistics and facts regarding the extent, composition, and management of both private and State-owned woodlands in Yorkshire and of forest research in the county are recorded.

I. *Introductory and Historical*

YORKSHIRE in very many ways holds a unique position among the counties of Great Britain. Larger by half than any other county in the land, her broad acres lie astride the central waist of the island, stretching from a hundred miles of eastern seaboard, in a compact block, to within a few short miles of the Irish Sea. Within her boundaries one finds an extraordinary range of geographical, geological, climatic, and sociological conditions, and yet the whole county and its people are strongly knit together with a natural individuality and cohesion. Within the county one finds a Britain in miniature and the history of Yorkshire is the history of Britain.

The boundary between the two fundamentally contrasting halves of Britain, the *highland* or north-western zone and the *lowland* or south-eastern zone, splits the county, running from Scarborough along the southern fringe of the North York Moors and thence south along the eastern foothills of the Pennines. Basically the lowland zone is an area of relatively young sedimentary rock formations, low elevations, low rainfall, more extremes of summer and winter temperatures with much arable and pines the most important conifers. On the other hand, the highland zone tends to older sedimentary and igneous rocks, mountains, and a humid, mild 'Atlantic' climate with mostly stock and sheep farming and spruces the most important conifers.

With examples of nearly all the country's most important types of relief, rock formation, climate, vegetation, and land utilization represented, there is a wide and comprehensive range of woodland site types in Yorkshire. The purpose of this article is to give a brief survey of these site types and the factors which determine them, and to record the present extent, composition, and management of both the private and State-owned woodlands of the county.

Historically, the story of Yorkshire's woodlands is in step with the broad story of England as a whole. From the peat deposits and soils of the county comes much evidence of the state of the vegetation, and the kinds of civilization which inhabited Yorkshire down through the succeeding prehistorical periods which followed the final retreat of the ice about 11,000 years ago. The Mesolithic hunters of the warm *Boreal* period lived amid pine and birch woods on the high uplands.

They were followed, towards the end of the succeeding cool, wet *Atlantic* period, with its extensive broadleaved woodlands, by Yorkshire's first agriculturists, the Neolithic farmers. In turn they gave way to the much more numerous Bronze Age settlers, who grazed their flocks and herds and cultivated wheat on the tops of the Wolds and on the North York Moors, which were then free of heather and severe podsolization. There are a number of Neolithic 'Long-Barrows' in East Yorkshire, and countless round Bronze Age tumuli across the Moors. The flint tools of all three civilizations continually turn up on the bulldozed roads and deep ploughed afforestation areas of the North York Moors, now with soils degraded to poor podsols and heather infested after centuries of constant burning and overgrazing.

TABLE I. *Yorkshire. Area of woodlands as a percentage of total land area*

(Approximate position as at September 1959—both privately owned and State woodlands combined.)

(1) *County*	(2) *Total area of county (acres)*	(3) *Approximate area of woods (acres)*	(4) *Col. (3) as % of col. (2)*
North Riding	1,356,316	84,000	6
East Riding	748,263	18,500	2½
West Riding	1,771,802	71,000	4
YORKSHIRE (whole county as at Sept. 1959)	3,876,381	173,500	4½
ENGLAND (whole country as at 1947–9)	32,032,797	2,000,000	6¼

The above figures include both N.E. (E.) and N.W. (E.) Conservancies.

Up to and throughout Roman times, most of lowland Yorkshire was heavily forested and ill-drained, cultivation being restricted to the drier soils of the less heavily wooded uplands and better-drained glades in the plains. Much more active clearance and draining of the oak, birch, and alder woods of the plains took place in Saxon times, but with the advent of the Normans, the Saxon agriculturists were severely harried and the area of uncultivated waste and woodland extended.

As in other parts of England, Yorkshire had in Norman times many great royal hunting forests. The Forest of Galtres stretched from the gates of York for 20 miles to Boroughbridge; Pickering Forest, 24 miles by 6 miles, was famous for its boars; Whitby, Danby, Wensleydale, Knaresborough, and Stainmoor are other examples. Wolves were found at Marske near Richmond as late as A.D. 1369 and there were great numbers of red and fallow deer.

As the great Yorkshire religious houses developed during the thirteenth and fourteenth centuries and wool became a commodity of supreme importance, there was constant friction between the foresters and their harsh laws and the agricultural interests of the religious orders and the common people. Gradually wool and agriculture won and the royal hunting forests were whittled away, a process which continued with increasing speed right up to the time of the agricultural recession of the nineteenth century.

During the eighteenth and nineteenth centuries, industrial prosperity and the period of build-up of the great estates with their mansions, parks, and amenity woodlands had a strong impact on the Yorkshire scene, and the majority of the privately owned woodlands in the county today owe their present shape and position to the estate building activities of that period.

The Forestry Commission made its first acquisitions in Yorkshire, on Selby and Allerston forests, in 1921, and by 1944 held 25,500 acres in the county with 15,683 acres of plantations. By 1949 the area of land held had risen to 39,500 acres

TABLE II. *Yorkshire. Total woodland area by ownership and productivity classes*

(Approximate position at September 1959.)

(Forestry Commission data, up to date, from Annual Reports rounded to nearest 100 acres. Private estate data based on estimated corrections to Census figures of 1955 (North and East Ridings) and 1947–9 (West Riding).)

Ownership	*High forest = Productive (acres)*	*Other = Non-productive (acres)*	*Total (acres)*
Private estates	82,000	38,000	120,000
Forestry Commission . . .	43,300	10,000	53,300
Totals	125,300	48,000	173,300

Figures include both N.E. (E.) and N.W. (E.) Conservancies.

Areas classified by the Census as High Forest have been taken as productive, and all other classes as unproductive (see text).

The Forestry Commission's 10,000 acres non-productive consists of felled woodland acquired from private estates and awaiting replanting. Bare land acquired and awaiting afforestation is *not* included in this table.

and the plantations to 18,577 acres, while the current position in September 1959 is 76,369 acres of land, of which 43,287 acres carry plantations.

II. *General Site Factors*

PHYSIOGRAPHY AND GEOLOGY

The Vale of York is flanked on either side with areas of high ground, to the west the foothills and then the main range of the Pennines, to the east the North York Moors, the Howardian Hills, and the Yorkshire Wolds. The Triassic bed rocks are thickly covered with glacial and recent deposits; Lacustrian clays, sands, gravels, and wharp to the south and Boulder clays, glacial sands, gravels, and moranic material to the north.

The Pennines run north and south down the western flank of the county for 100 miles with a width of 30 to 40 miles. The highest ground, the backbone of the chain, lies well to the west, and in its northern half is a region of fine mountains, wild moorland, limestone scars, and deep sheltered valleys of great beauty—the famous Dales.

The South Pennines and the Yorkshire Coalfield. South of the central east–west pass formed by the lower valleys of the rivers Wharfe and Ribble, the mountain

limestone disappears and the country changes markedly in character. There are no prominent mountain peaks, the maximum elevations are rather lower and the millstone grit backbone of high ground, which separates the coalfields and industrial regions of the West Riding from those of Lancashire, becomes a relatively narrow ridge. The mill towns crowd the valleys along the flanks of the main ridge and industry and coal-mines sprawl across the Pennine foothills.

The Magnesian Limestone Belt. The 200 foot contour line marks approximately the western edge of the Vale of York and the first beginnings of the foothills of the Pennine region. This is the narrow ridge of the Permian Magnesian Limestone, which shelves up from below the glacial and recent deposits of the Vale to form a low west-facing escarpment, with striking limestone gorges where the main rivers cut through to the Vale. From a little north of Wetherby to the Tees the limestone bed rock is almost entirely obscured by thick layers of Boulder clay.

The North York Moors form a distinctive and well-defined feature in the north-eastern corner of the county, an upland plateau of Jurassic rocks with a general elevation of 300 to 1,200 feet above sea-level and no marked summits. To the west and north-west this region presents an irregular but sharply defined escarpment to the Vale of York, while on the east there are 40 miles of coast-line with many high, spectacular cliffs. The plateau is deeply incised with a system of river valleys or dales which break the monotony of the unenclosed moors and provide shelter and more fertile ground.

The Howardian Hills, also composed of rocks of the Jurassic period, are 300 feet to under 600 feet high and comprise a range of undulating hills less than 20 miles long and nowhere more than 5 or 6 miles wide. The whole area is extensively faulted and it is separated from the North York Moors by a rift valley at Ampleforth.

The Wolds have typical chalk upland contours, sweeping curves, and frequent dry valleys formed, no doubt, by river action during the glacial period when summer melt-water flowed at the surface, its downward percolation prevented by frozen subsoil.

Holderness. The chalk formations of the Wolds, falling away from the western and northern escarpments, dip to the south and east below the glacial and recent deposits of the low-lying clay plain of Holderness. Though everywhere of very low elevation, much of Holderness has an undulating surface typical of flat stretches of relatively young boulder clay deposits.

The Vale of Pickering. Enclosed by the Moors, the Howardian Hills, and the northern edge of the Wolds is the small Vale of Pickering, a level plain which was an Ice Age lake. The bed rock over almost the whole of the Vale is Kimmeridge clay, but very little of this outcrops from below thick deposits of silt, gravels, peats, and sands which are relics of the former glacial lake.

Sources of geological information. For a full account of Yorkshire geology two excellent publications of the Geological Survey are available, 'The Pennines and Adjacent Areas' (1954) and 'East Yorkshire and Lincolnshire' (1948). Post-war drift and solid 1 inch maps are available for practically the whole of the industrial West Riding. New sheets are also available for a strip down the east coast from

TABLE III. *Summary of Yorkshire geological formations*

(Those in italics outcrop on a large scale and are important.)

Age (millions of years)	*Period formations*	*Main rock types and remarks*
	QUATERNARY	
	POST-GLACIAL (= RECENT)	(The last 11,000 years) *Alluvium*, *Peat*, *Fenland Deposits*, *River gravels*, *Blown sand*.
	GLACIAL (= PLEISTOCENE)	*Boulder Clay*, *Glacial Sands*, *Gravels*, *and Lake Deposits*, *Moraine*, Head.
1	TERTIARY	No deposits in Yorkshire. Period of erosion and landscape formation. Major earth movements. Cleveland dyke formed.
55	CRETACEOUS	
	UPPER	*Upper Middle and Lower Chalk*. All similar: solid chalk; laid down in a great sea far from land and rivers.
	LOWER	Red Chalk, Speeton Clay. Only very minor outcrops. Dry land and erosion for a considerable period of time after close of Jurassic.
105	JURASSIC	
	UPPER	*Kimmeridge Clay*.
		Corallian, *Upper Calcareous Grit*, *Upper Limestone*, *Mid. Calc. Grit*, *Lower Limestone* (*Passage beds*), *Lower Calc. Grit*. Fine grained grit stones and Oolitic limestones.
		Oxford Clay. Shales and Clay.
		Hackness Rock. Massive sandstones, e.g. at Sutton Bank.
		Kellaways Rock. Shales below, thick soft sandstone above.
		Cornbrash. A very narrow band of shelly limestone.
	MIDDLE	*Upper Estuarine Series*. *Grey Limestone*.
		Middle Estuarine Series. *Lower Estuarine Series*. *Dogger*. Shales, sandstones, quartzite and impure limestones, and ironstones. Some current bedded and some level bedded. Deltaic deposits from a vast river system flowing from the north.
	LOWER	*Upper*, *Lower*, and *Middle Lias*. Rhaetic. Clays and Shales with numerous subordinate ironstones, calcareous mudstones, limestones, and sandy bands, all deposited in the shallow, muddy sea which came into being in Rhaetic times. Little or no sandy material.
145	PERMO-TRIASSIC (or NEW RED SANDSTONE)	Keuper Marl, Sandstone, and Waterstones.
		Bunter sandstone.
		Permian Limestones (= *Magnesian Limestone*), *Marls*, and sandstones.
		The Permian and Triassic rocks appear to have accumulated under arid or desert conditions, a landlocked inland sea. Wind worn sand, dolomite, gypsum, salt, &c., from evaporation processes. All tend to be red in colour or weather to red soils.

Age (millions of years)	*Period formations*	*Main rock types and remarks*
205	CARBONIFEROUS	*Coal Measures: mudstones, sandstones, and coals.* Beds laid down by rhythmic deposition in semi-fresh water swamp over a vast period of time. Mudflats formed, were colonized with dense forest, then subsided and plant remains (now coal) covered with silt and sand, eventually reaching surface and whole process repeated again and again. Seams roughly 30 feet apart, coal followed by mudstones, siltstones, sandstones, then fireclay or ganister. Total thickness 3,000 to 4,000 feet. *Millstone Grit Series: Mudstones* and *shales*, with beds of *sandstone* and *grit*. Maximum thickness 6,000 feet. Rhythmic marine sedimentation, with sequence: Coal (occasional), marine mudstone, sandstone—frequently coarse-grained and in very thick beds. *Carboniferous Limestone Series*: (The *Mountain Limestone*): *mudstone*, *limestones*, rare sandstones; with lower part of '*Yoredale Beds*'. Very massive limestone, laid down in clear water of a slowly subsiding sea bed, followed in the northern part of our area by the rhythmic depositions of the mudstones, limestones, and sandstones of the 'Yoredale Series'.
285	DEVONIAN (?)	Rocks attributable to these periods outcrop to a very limited extent in the extreme west of Yorkshire, in the Upper Ribblesdale and Ingleborough area. They are of little significance in forestry.
335	SILURIAN	
375	ORDOVICIAN	
425	CAMBRIAN (?)	
485	PRECAMBRIAN	
2000		

Whitby to Bridlington, but at present there are no post-war sheets for any of the rest of Yorkshire. The pre-war 1 inch sheets are completely unobtainable, and it is quite difficult to locate specimens which may be consulted for reference. A complete set of all published sheets is available with the Department of Geology at Leeds University.

CLIMATE

Rainfall: Mean annual precipitation. The central Vale of York and the adjacent lowland portions of the Pennine foothills form one of the driest regions of the British Isles. This is attributable to the high ground to the west and east and especially to the line of the Pennines which forces all air coming from the west to at least 1,000 feet elevation, thus producing quite heavy rainfall on the western slopes and the higher hills, but casting a rainfall 'shadow' up the full length of the Vale of York.

In the south, near Selby and Doncaster, there are areas with less than 22½ inches

of rain each year and there is a central belt, right from the Humber to the Tees, which throughout averages below 25 inches. To east and west of this central lowland dry belt there is increasing rainfall with increasing elevation, giving averages over 30 inches on the highest parts of the Wolds, over 40 inches on the highest parts of the North Yorkshire Moors, and substantial areas with 50 and 60 inches on the highest parts of the central Pennine Chain.

Precipitation régime. Although the mean annual precipitation is so much lower in the central lowlands, the distribution régime in these areas is relatively favourable due to the local effects of summer convection storms. Normally there is a protracted period of relatively low precipitation in winter and early spring, and a pronounced maximum in the latter half of the summer and in the autumn.

Water availability. There is a pronounced summer evapo-transpiration deficiency over the whole of the Vale of York and over almost the whole of the eastern uplands while across the Pennines there is an equally marked summer evapotranspiration surplus.

Temperature. Yorkshire experiences a typical east coast temperature régime with relatively cold winters and hot summers.

Spring frosts are severe in the central lowlands and in enclosed valleys and depressions in the eastern uplands. The generally low winter temperatures and frosts during the growing season preclude the growing of tender exotic species over most of the county.

Phenological records of flowering and leaf burst suggest that the arrival of spring is 10 to 12 days later in the York area than at comparable elevations and sites in the South Midlands.

Exposure. Over the whole region the prevailing winds are westerly and south-westerly and on high ground, except where local configuration deflects wind currents, the lean of wind-moulded trees is away from the south-west. Near the east coast salt burn shows its influence for several miles inland where there is no intervening cover, but in sheltered valleys trees relatively tender to exposure can do well within a few yards of the beach.

Gale damage occurs intermittently on a moderate scale. The last extensive damage was on 1 March 1956 when a gale struck on a narrow north–south line along the Pennine foothills from near Barnsley to Barnard Castle. Approximately one million cubic feet of timber was flattened by that gale.

Atmospheric pollution. In the industrial region of the West Riding atmospheric pollution is the over-riding limiting site factor. The presence of pollution is everywhere apparent in the grime which clogs the vegetation and blackens alike the houses, the sheep, and one's shirt collar.

Everywhere in the industrial area the atmospheric pollution severely limits the forester's choice of species. At the lower elevations broadleaved species often meet the situation, but at higher elevations in the South Pennines the difficulties are indeed great, for not only does high elevation preclude any prospect of profitable hardwood forestry but the effects of pollution cum exposure are doubly severe.

SOILS AND VEGETATION

The *Vale of York* has very variable soils, almost all of them of glacial and recent origin. Near Escrick and York there are low crescentic moraines composed of sands and sandy silts and areas of similar light soils cover large areas along the ancient shoreline of the glacial lake which once covered virtually the whole of the plain south of York. Beds of Lacustrine clays and silts cover much of the very flat south central portion of the Vale, and beds of wharp and fen peat follow the rivers.

Originally this area had extensive marshes and meres and broadleaved woodland of willows, alders, oak, and birch. Such woodland as is now found is largely on the lighter soils, which are often highly acid. Birch grows very freely and in time replaces the heather and *Molinia* which dominate poor acid wet soils which have been allowed to revert from agriculture. *Rhododendron ponticum* has been introduced as game cover and frequently flourishes, spreads, and forms dense persistent woodland undergrowth. On the plains drainage is everywhere a great problem.

On the *Wolds* the chalk is everywhere near the surface, and the soils thin dry rendzinas. The farming is highly arable and only occasional steep valley slopes show any sign of natural vegetation and here a coarse turf of *Brachypodium* predominates. There is little sign of the profuse herbaceous calciphile flora which is such a feature of the southern chalklands. Ashwood (*Fraxinus*) is the natural vegetational climax of the Wolds—eventually colonizing after pioneer crops of whitethorn (*Prunus*) have invaded grassland.

Like the Wolds, the *North York Moors* soils are mostly derived from the bed rock immediately below, drift being restricted to the north-east. The moorland soils are mostly very poor silty sands, highly podsolized, or gleyed clays. There is a thin skin of peat over much of the moorland, and occasional areas of deep blanket bog. The dominant vegetation on the flat tops is heather, while bracken is normally found on the well-drained slopes and oak and birch scrub with rushes, brambles, and grass on the heavier and wetter soils of the dale bottoms.

The millstone grit of the higher *Pennines* frequently carries deep blanket bog, with heather and *Molinia* or cottongrass. Sphagnum is conspicuously absent from the South Pennines, possibly due to the effects of atmospheric pollution. The highest mountain limestone areas also often carry deep peat and moorland vegetation. Limestone at moderate and lower elevations forms a fine fescue grass sward. Outcrops of rock, scars, limestone screes, and pavement are frequent. There is a very varied and interesting herbaceous flora. Ash woodland is the natural climax on the valley slopes.

There are considerable areas of limestone soil on the *Corallian* formations around the Vale of Pickering and on the *Magnesian limestone* from near Wetherby to the southern edge of the county. Where the rock is near the surface, the soils are rendzinas, and the natural vegetation is distinctly calciphilous.

BIOTIC INFLUENCES HARMFUL TO FORESTRY

Mammals

Rabbits caused very great damage to trees in the county before the advent of myxomatosis. The numbers were reduced drastically in all parts of our area during

the early years of the disease but the relief has proved very temporary, for rabbits have survived everywhere and in many places quite considerable populations have reappeared. Myxomatosis is still frequent but it is now sporadic in its appearances and is rarely capable of extinguishing rabbits rapidly over extensive areas. There are still a few places where plantations can be raised without rabbit netting—but these are very few. Rabbit Clearance Societies have been set up in all three Ridings, the North Riding having been particularly energetic in this respect with eighteen in operation by November 1959, but it is still too early to judge their effectiveness.

Hares are present everywhere and they are common in certain regions, notably on the Wolds, where they cause a lot of harm in young plantations.

Grey squirrels have been present in most parts of Yorkshire for many years, Castle Howard being one of the original centres from which these animals were introduced and allowed to spread. Damage to sycamore and beech is frequent and sometimes severe, but not usually on the wholesale scale that is so common in southern England. Since the bonus for squirrel destruction was removed there are signs that grey squirrels are beginning to increase.

Red squirrels are rare in this county and very restricted in range. They cause no damage.

Insects

Pine looper (Bupalus) is found wherever pines are planted, but check surveys by the Forest Entomologist indicate that numbers are nowhere at danger level.

Coleophora, the larch leaf miner, swarms almost every year on both Japanese and European larch in many parts of the county. In some places—as at Dalby in Allerston Forest—defoliation in early summer has been almost complete for a number of successive years, and it is for consideration whether these attacks are a contributory cause of the serious premature fall-off in larch crop increments which are under investigation in Allerston.

Neomyzaphis very frequently causes severe defoliation of Sitka spruce (*Picea sitchensis*)—the defoliation being noticeably more severe in the eastern and more dry parts of our area than in the western regions of heavier rainfall. In bad years, by about June defoliation may be almost complete, though in most crops individual trees seem to retain their leaves better. There seems to be room for the selection of a strain of Sitka with special qualities suited to the east British climate.

Fungi

Fomes has not yet been completely investigated and surveyed in this county so the impression one gets that it is a less damaging pest here than in many other areas may be partly an illusion. There have been several instances of serious butt rot in larch crops on private estates—and there are certainly indications that it may be particularly frequent on chalk and limestone.

Brunchorstia. The most spectacular disease in plantations in Yorkshire at present is undoubtedly the Corsican pine 'die-back' in Dalby Beat, Allerston Forest. This disease has been known in the Dalby area for 10 years or more, but during the past 5 years it has spread rapidly in young pole crops of Corsican pine (*Pinus nigra* var.

calabrica). The fungus *Brunchorstia* seems to be very strongly suspect though climatic and soil factors may also be involved. In Dalby beat several hundred acres of Corsican pine plantations are now affected in varying degrees and plans are being made to convert these areas to other species.

The use of Corsican pine in Allerston District, where fortunately we have plenty of alternative species to choose from, has now been stopped. However, it is still being planted on a fairly large scale in the industrial areas of the West Riding where it is the conifer best able to resist the effects of atmospheric pollution. At present this area is free of 'die-back' disease but we are concerned lest it appear there to rob foresters of almost their only smoke resistant conifer.

Lophodermium. This disease is rife on all species of pine throughout the county.

During the past 5 years the Forestry Commission has developed 'Woodland Nurseries' for growing conifer seedlings in the Allerston District. Initially all these areas were carved out of pole-sized pine crops on sandy soils and the build-up of *Lophodermium* during the sequence of wet summers from 1956 to 1958 made its appearance with increasing severity among the pine seedlings. The trouble culminated during the 1958 summer and eventually over two million 1-year-old pine seedlings had to be destroyed in the Allerston District nurseries. Steps have now been taken to obtain new seed beds for woodland nurseries in pine-free larch crops and all the 1959 sowings of pine have been carefully segregated to avoid getting seedling infection by *Lophodermium.*

The relative susceptibility of the different pine species, both in the forest and in the nursery, as observed in Yorkshire in the spring of 1959 is as follows:

TABLE IV. *Relative effects of attack of Lophodermium on pines*

	Mild	*Serious*	*Very severe*
Pole stage in moorland plantations	Lodgepole (*Pinus contorta*) Corsican	..	Scots ..
Seedling stage in woodland nurseries	Lodgepole	Scots (*Pinus sylvestris*)	Austrian (*Pinus nigra* var. *austriaca*) Corsican Mountain (*Pinus mugo*)

Man. Trespass and Fire

Trespass and physical damage. The cost of a fence capable of resisting children from the nearby mining village is an almost prohibitive item when one comes to planning planting schemes on mine tips and other industrial waste land.

Fire. During the very dry summer of 1959 the number of fires in plantations, both on private estates and on Commission land, were greatly in excess of the normal. Private forestry lost considerably more than did the State plantations.

The local Fire Services are most helpful and give very willing and efficient assistance. On the whole the general public react with sympathy and understanding, displaying discretion in avoiding fires, or reporting them when seen and sometimes helping to put them out.

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The local Fire Services are most helpful and give very willing and efficient assistance. On the whole the general public react with sympathy and understanding, displaying discretion in avoiding fires, or reporting them when seen and sometimes helping to put them out.

The Forestry Commission have a radio system to assist in fire detection and fire fighting in the North Yorkshire Moors area. There is a main station, three radio-equipped Land Rovers, and ten pack sets.

III. *Economics and Administration*

LAND UTILIZATION

For detailed accounts, reference should be made to the Land Utilization Survey of Britain (Beaver, 1941; Dudley Stamp, 1942; Wooldridge, 1945.)

Industrial development is densely concentrated in the southern part of the West Riding on the Yorkshire Coalfield. The great woollen towns—Leeds, Halifax, Huddersfield, Dewsbury, and a score of others—are in the northern part of the coalfield and in the adjacent valleys of the Pennine flanks. Soft water from the adjacent millstone grit moors has been the decisive factor in the evolution of the woollen mills, along with power from stream and mine. The whole of the coalfield is subject to intensive mining and there are many consequential industries—smelting, metalwork, chemical, and clothing manufacture.

Throughout some 500,000 acres of the West Riding, the dominating land use is industry, and before the great financial interests involved, agriculture and forestry are tolerated only so long as they occur on land not immediately needed for dirtier but more lucrative purposes. Great stretches of land are occupied by houses, factories, roads, railways, pit and spoil heaps, and more is laid waste, temporarily or permanently, by opencast mining and by subsidence from deep mining activities.

There is a smaller Teesmouth industrial region with important chemical works, shipyards, and steel works.

As far as forestry is concerned, the effect of atmospheric pollution is dramatic and controls completely the pattern and direction of all forestry activity in the industrial and adjacent regions.

Water catchment. The great industrial regions require immense supplies of water for domestic and factory use, and the whole of the southern portion of the main Pennine Uplands is one vast network of Water Undertakings. The value of the mountain regions for this purpose is paramount. Some authorities do not like grazing animals on their catchment grounds and if only the atmosphere was clean enough to permit of the healthy growth of conifers at the high altitudes, there would be considerable scope for large-scale catchment ground forestry. Leeds Corporation has large and quite successful catchment plantations in the comparatively clean atmosphere of their Fewston reservoirs, west of Harrogate. A number of other waterwork authorities have attempted catchment planting. The results are, in general, in inverse relationship to degree of pollution and altitude.

Farming is the main industry over some 3,000,000 acres of Yorkshire, and even in industrial areas agriculture plays an important secondary role.

The richest arable land, with cash crops of grain, sugar beet, and potatoes and intensive mixed farming is found in the York Plain, Holderness, and the Vale of Pickering. There is also much arable land, of generally lower value on the Wolds, the Magnesian limestone and the Corallian limestone areas around the Vale of Pickering.

The Upland regions of the North York Moors and the Northern Pennines are important sheep-rearing areas, and everywhere the heather moorlands have high value as grouse moors.

Cattle rearing and milk production is the dominant method of farming in the Lower Dales, the Middle Dales, and over much of Ribblesdale and the western lower Pennines.

Forestry. Woodlands in Yorkshire occupy only 4¼ per cent. of the total land area of the county (see Table I). This is well below the average for England. The relative importance of forestry varies greatly from one region of Yorkshire to another. On the main Pennine range, throughout its length, there is practically no woodland and the Vale of Pickering and Holderness have few plantations.

The most important woodland regions are the North York Moors, the Howardian Hills, and the Dales Foothills, for in these regions the land is often marginal in agricultural value, though very suitable for forestry, and there is no competition from industry.

FORESTRY COMMISSION ADMINISTRATION

The North-East (England) Conservancy, which covers Northumberland, Durham, and most of Yorkshire, has its headquarters at York. For the sake of convenience, the extreme north-western portion of the West Riding is, however, detached and included in the North-West (England) Conservancy, which has its headquarters at Chester. The main area in the N.E. (E.) Conservancy is divided into five Forestry Districts, each in charge of a District Forest Officer.

Each of these District Officers is responsible, within the limits of his own district, for all matters relating both to private woodlands and to State forestry, and in the Conservancy Office there is one Forest Divisional Officer, responsible to the Conservator, for co-ordinating the work of the five Yorkshire districts, which together are one half of the Conservancy.

There are twenty-three State 'forests' in the N.E. (E.) Conservancy portion of Yorkshire, and the N.W. (E.) Conservancy has Gisburn Forest and parts of Bowland Forest in the Ribblesdale area, and a few completely detached woodlands to the south-east of Sheffield, which, for administrative convenience, are appended to Sherwood Forest.

The Yorkshire 'forests' are listed by districts in Table X, the largest being Langdale with 14,810 acres and the smallest Bingley with only 57 acres. Within 1960 there is likely to be a reorganization of Yorkshire's 'forests' with considerable amalgamations and a reduction in number. At present seven of the largest forests are each divided into two separate Foresters' charges, while in Dales District five forests are aggregated into a single charge. There are twenty-five independent foresters' charges in the N.E. (E.) portion of Yorkshire. At September 1959 the local supervisory staff numbered 49 and there were 460 forest workers.

THE ORGANIZATION OF PRIVATE FORESTRY

The Royal Forestry Society of England and Wales has a progressive and vigorous Yorkshire Division, which covers the whole county. In September 1959 the

Division organized a most successful one-day Forestry Conference at Harrogate. In May 1960 there is to be a Forest Machinery Exhibition on the permanent showground of the Yorkshire Agricultural Society, largely as a result of the initiative of the Division.

The Timber Growers' Organization is being developed to correspond with Conservancy boundaries, and there is to be a Yorkshire Sub-Branch.

Co-operative Societies have hitherto not been prominent in Yorkshire. The only society in the Conservancy is Northern Forestry Products, which has so far operated mostly in Northumberland and Durham, with limited activities in the North Riding. The Timber Growers' Organization plans to use Northern Forestry Products as their agents in north-east England, and with this in view arrangements are on hand to extend the Society's organization to serve adequately the whole of Yorkshire.

Forestry contractors and *consultants* are available on a reasonably adequate scale, but there is plenty of scope for the Timber Growers' Organization to arrange better co-ordination.

MARKETS FOR FOREST PRODUCE

Conifers. The main market for conifer thinnings is round mining timber, which goes to the Yorkshire and Nottingham coalfields in the south and to the Durham and Northumberland coalfields in the north. Many private estates use most of their own production of larch of all sizes for local estate use such as fencing, repairs to farm buildings and houses. Larger conifer timber is normally sold to the trade, whence it finds its way into various markets in the big industrial areas of the West Riding and Teesside.

For most of Yorkshire there is at present no convenient pulpwood outlet, nor is any mill likely to be started in north-east England in the near future. A small amount of pulpwood is now crossing the Pennines to Bowaters' Mill in Merseyside, and this mill is within satisfactory reach of the Ribblesdale region of Yorkshire.

Broadleaved. Large-sized high-quality butts of all species of hardwoods fetch a good price and have a steady sale. The normal outlet is via the trade timber merchants.

Poor quality hardwoods are difficult to market at present and timber merchants are very reluctant to buy lots which do not include a fair proportion of quality timber. Much of the lower-grade material is converted into sawn mining timber such as lids and sills, but the margin of profit on present National Coal Board prices is very low indeed.

Oak deserves special mention, for there is a good deal of mature and overmature timber on private estates in the county. The best quality butts always have and always will fetch satisfactory prices, but much of the timber is of moderate to poor quality. Previously second-grade oak logs found a good steady market in the railway wagon works at Darlington and Doncaster, but this outlet has ceased and logs of this type are now a drug on the market. It is difficult to see much future in growing oak in Yorkshire.

Sycamore (*Acer pseudoplatanus*) is another species which deserves special mention,

and here the story from the marketing angle is much more rosy. Sycamore appears to grow more satisfactorily in Yorkshire and the immediately adjacent areas to the north and west than anywhere else in Britain. In this region there is at present a ready and satisfactory sale for all sizes from first thinnings upwards. Poles are in very good demand for turnery, medium-sized logs can be sold satisfactorily, while clean high-quality butts of 18 inch quarter girth and up consistently sell well. During the past 2 years veneer quality logs have been fetching prices which are quite exceptionally high, butts with normal straight grain up to 20*s*. per h. ft. standing and butts with good 'curly' grain over £4 per h. ft. Such prices will not last indefinitely, but a ready market for good quality sycamore will continue.

Hardwood poles from thinnings are at present very difficult to sell anywhere in the county. The exceptions are clean grown sycamore and birch for which profitable turnery markets exist in the West Riding and on Teesside. For this market the birch has to be felled with sap down, and the poles 'spotted' to ensure proper seasoning. The sycamore poles can be felled at any season and no spotting is necessary.

AMENITY AND SPORTING

Amenity. Parts of Yorkshire are deservedly famous for their beauty and recreational value. The North Yorkshire Moors National Park covers almost the whole of that region, and includes 396,000 acres of land. This is potentially the most promising area for the expansion of State forestry in Yorkshire, but there is considerable resistance against large-scale planting from various bodies interested in preserving the present character of the open moorland. This is to some extent understandable, but there is still plenty of scope for afforestation, especially on the valley slopes, and carefully planned forestry can undoubtedly contribute to the future beauty and interest of this region.

Parts of the Dales National Park and The Peak National Park also extend into Yorkshire, but there appears to be no clash of interest between forestry and amenity interests in these areas.

Wherever plantations are being made on hilly ground in this county, it is necessary for amenity to be borne in mind when planning species-pattern, and roads. It seems certain that in the future the State forests of Yorkshire will make an increasingly valuable contribution to the recreational needs of the large urban population of the West Riding. It is essential to bear this in mind with all forest planning.

The amenity value of the woodlands and park trees of the great estates of the county cannot be over-estimated. The Planning Authorities of the West and North Ridings are particularly alive to this, and well realize that the future of these assets can only be assured so long as the main estates are not broken up.

Sporting. Most Yorkshire estate woodlands have been laid out with sporting interests in view—indeed, many of the woodlands were designed purely as sporting coverts. Economic forestry considerations are steadily gaining ground due to processes of enlightenment and financial necessity rather than any decline in the value

and importance of pheasant shooting or fox hunting. Even today there are a number of estates where the sole interest in the woodlands is their sporting value. There are also some excellent object lessons in the art of successfully combining high-grade sporting and sound economic forestry. There is very little sporting value in the Commission's large plantations in Allerston District.

IV. *The Woodlands and Their Management*

WOODLAND STATISTICS

Sources of information on the area and types of woodland in the county are the departmental Conservancy Annual Reports and the various published reports of the Census of Woodlands, 1947–9 (Forestry Commission, 1953). A revised census of the woods in the North and East Ridings was taken in 1955, but the resultant data have not been printed and published.

For the purposes of this article, estimated corrections have been made to some of the census data in order to bring them up to date. All areas given refer to woods of 5 acres and up in area.

Individual county surveys have not been made of woods below 5 acres, but a randomized census estimate shows that the total area of woods 1–4 acres in area is about 6 per cent. of the total area of woods of over 5 acres. Thus in Yorkshire there are about 10,000 acres of such woods.

Area of woods as a percentage of total land area is shown in Table I. The East and West Ridings, with only 2½ and 4 per cent. of their area under woodlands, belong to a group of eastern and midland counties which have a far lower proportion of woodlands than the national average of 6¼ per cent. The North Riding is about average at 6 per cent., with its total steadily rising due to large-scale Commission afforestation.

Types of woodland are summarized in Table II, from which it may be seen that the present Yorkshire total of approximately 173,000 acres is divided in the proportion of 69 per cent. privately owned and 31 per cent. State woodland. With the Commission now planting at a steady rate of 3,000 acres annually against about 1,000 acres by private owners, and the privately owned total dwindling by perhaps 1,000 acres a year by transfer through acquisition to the Forestry Commission, the relative proportion held is swinging steadily in favour of the Forestry Commission.

In Table II woodland classified as 'High Forest' by the Census has been accepted as being 'Productive', the 'Other' or 'Non-productive' being taken to include the census classes 'Coppice', 'Coppice with standards', 'Devastated', 'Scrub', and 'Felled'. The census coppice and coppice with standards total only 343 acres and this consists mostly of poor quality alder, birch, elm, oak, and sycamore regrowth —little, if any, of which is actively managed as coppice. The total 'unproductive' area of 48,000 acres is almost equally divided between (*a*) coppice, scrub, and devastated, and (*b*) felled areas.

Relative importance of species. Table V shows the relative importance of the principal species growing in high forest in Yorkshire. Pure and mixed stands of all

age classes are combined, and separate figures are given for State and privately owned woods in each of the three Ridings.

Note how privately owned woods are predominantly broadleaved, with oak, ash, and sycamore most frequent, while Commission woods are 90 per cent. coniferous in the North Riding, where the bulk of the State plantations are located, and

TABLE V. *Yorkshire. Tree species in high forest*

(Pure and mixed stands and all age classes combined. Areas by species as percentages of total areas of woodlands by ownership and counties.)

(Position at August 1955 (N. and E. Ridings), and 1947–9 (W. Riding).)

Ownership	*Private*			*Forestry Commission*		
Year of Census	*1955*		*1947–9*	*1955*		*1947–9*
County	*North Riding*	*East Riding*	*West Riding*	*North Riding*	*East Riding*	*West Riding*
	%	%	%	%	%	%
Scots pine	15	9	9	34	12	31
Corsican pine	..	..	..	7	26	3
Lodgepole pine	..	..	..	1	..	..
European larch	17	18	10	4	7	..
Japanese larch	5	2	1	16	5	1
Norway spruce	3	5	1	7	..	11
Sitka spruce	2	1	..	15	..	5
Douglas fir	1	..	..	5	1	..
Other conifers	..	..	1	1	..	..
Total conifers	43	35	22	90	51	51
Oak	22	13	29	2	9	2
Ash	9	21	6	1	6	29
Beech	5	9	10	3	23	..
Birch	7	4	7	3	9	11
Sycamore	10	12	23	1	1	2
Elm	3	4	2	..	..	..
Poplar	..	1	..	..	1	5
Other B/leaved	1	1	1	..	..	..
Total B/leaved	57	65	78	10	49	49
Total all species	100	100	100	100	100	100

almost equally divided between conifers and broadleaved in the East and West Ridings.

Distribution of age classes in the North Riding is shown diagrammatically in Fig. 1. This chart shows how there is at present:

(*a*) A fairly good distribution of age classes in privately owned broadleaved woods, with a lot of over-mature timber.

(*b*) A very uneven distribution of age classes in privately owned coniferous woods—a severe lack of middle and old age-classes (result of heavy war

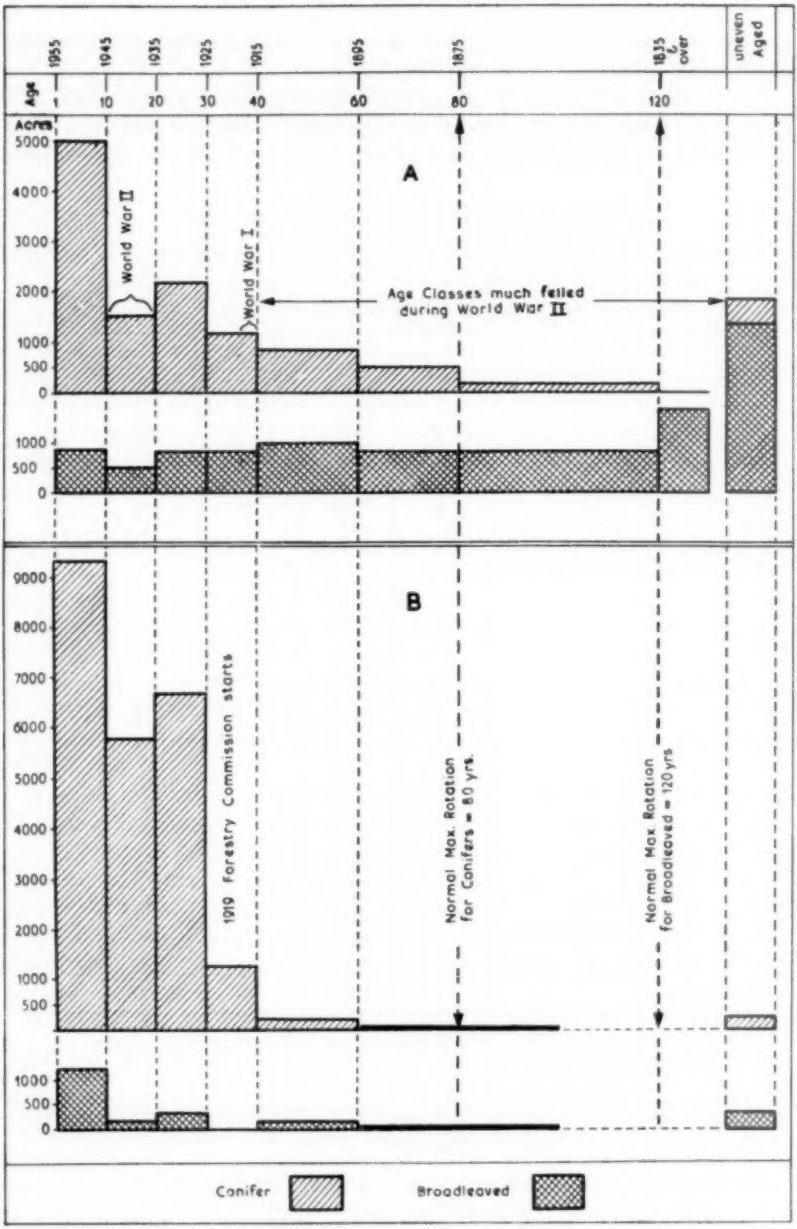

FIG. 1. North Riding, Yorkshire. Age-class distribution of High Forest areas as at September 1955.
A, Privately owned. B, State owned.

fellings) and a great increase of conifer planting relative to broadleaved since 1945.

(*c*) A very unbalanced age-class distribution in the State-owned plantations—reflecting the short history of the Commission since its inception in 1919, its accelerating rate of planting, and the predominantly coniferous character of the State plantations (but with a swing to 10 per cent. broadleaved plantings since 1945).

SITE TYPES AND CHOICE OF SPECIES

The notes which follow indicate the main forestry site class groups in Yorkshire, and the species selection followed currently in Forestry Commission planting in those areas. Private owners in general follow the same lines but with a bias to larch and broadleaved species, with estate timber needs and sport in mind.

1. *Vales and plains.* The Vales of York and Pickering; Holderness; old woods and replanting.

Main site factors. Very variable soils; low rainfall, spring frosts, and difficult drainage. Locally birch and rhododendron scrub very troublesome.

Species planted. Wide range of possibles: oak, sycamore, Scots and Corsican pines, larch. Minor importance—beech, Norway spruce (*Picea abies*), and poplar; hemlock (*Tsuga heterophylla*) for underplanting birch.

Avoid or use with great care—Sitka spruce, Douglas fir (*Pseudotsuga taxifolia*).

2. *Upland Heaths* and associated minor valley systems. North York Moors; upper parts of Pennine foothills and Middle Dales of North Pennine region (major valleys to group (3)); open moorland afforestation.

Main site factors. Poor, heathy, moorland areas with soils of low fertility. When sandy strongly podsolized, when clays strongly gleyed. Deep ploughing essential. Exposure considerable.

Species planted. Scots and Lodgepole pine (all soil types) Japanese and Hybrid larch (*Larix leptolepis* and *Larix Xeurolepis*) (sands and grits and middle slopes of valleys), Sitka spruce (peats, damp valleys, and in mixture with larch on better plateau tops), Norway spruce (on flush soils on slopes, in valleys), Douglas fir (lower slopes of small valley sides); hemlock has great possibilities but to date has not been used very much.

Avoid or use with great care—all hardwoods. Corsican pine (see notes on *brunchorstia*).

3. *Lower Foothills.* Howardian Hills; Lower foothills of the North Pennines; Lower escarpment and large valleys of North York Moors; Lower escarpment of the Wolds; divided between old woodland and afforestation of bracken slopes.

Main site factors. The most favourable forest land in the county. Variable soils, often with flush enrichment and frequently very fertile. Shelter and drainage usually good.

Species planted. A very wide variety possible, to fit different soil and shelter

types. All principal and minor species of both conifers and broadleaved trees have a useful place somewhere in this site-class type.

4. *The Upper Dales.* The North Pennine Highlands: mostly afforestation, if anything.

Main site factors. High rainfall; high elevations, precluding economic forestry on the tops. Variable soils, including much peat; heather, *Molinia*, and *Eriophorum*. Even limestone is peat covered at high elevations.

Species to plant. The peaty and the flush areas can grow good spruce (e.g. Arkengarthdale Forest which is 100 per cent. spruce). The valley sides in Upper Dales grow good larch and pine. For shallow soils over limestone, see (5).

Avoid Scots pine at high elevations.

TABLE VI. *Yorkshire. Plants used for planting season 1958*

(Forestry Commission, N.E. (E.) Conservancy. Number of plants used, by species, as percentage of total plants used by Forestry Regions.)

Forest Region	*North York Moors and Howardians*	*Middle Dales and Footbills*	*Coalfield*	*South Pennine**	*Wolds*	*Vale of York*	*Total P. 58 all N.E. (E.) in Yorkshire*	*All Yorkshire: all woods 1–10 years old P.W. and F.C.†*
Species	%	%	%	%	%	%	%	%
Scots pine	27	27	5	..	7	27	24	27
Corsican pine	..	2	17	39	2	23	4	4
Lodgepole pine	10	..	13	27	..	..	8	..
European larch‡	5	20	..	..	39	3	8	17
Japanese larch	22	20	25	9	..	4	21	17
Norway spruce	3	6	..	..	1	13	4	5
Sitka spruce	10	2	..	..	..	..	7	8
Douglas fir	3	2	..	..	..	1	2	3
Other conifers	1	1	..	..	5	..	1	1
Total conifers	81	80	60	75	54	71	79	82
Oak	3	3	..	..	..	10	3	3
Red oak	1	1	20	1	..	..	1	..
Ash	..	..	..	..	..	..	..	2
Beech	9	9	4	24	43	4	10	5
Birch	..	..	..	..	..	..	..	3
Sycamore	5	7	15	..	3	14	6	3
Other B/leaved	1	..	1	..	..	1	1	2
Total B/leaved	19	20	40	25	46	29	21	18
Total all species	100	100	100	100	100	100	100	100

* Small-scale planting in a relatively sheltered area.

† The right-hand column relates to the Census figures for High Forest for the youngest age class, 1–10 years, private and State owned combined.

‡ In 1958 the required quantities of European Larch were not fully available and in fact the figures given as European Larch include some Japanese Larch used in substitution.

5. *Limestone Regions.* The Chalk Wolds; Corallian limestone areas round Vale of Pickering; Magnesian limestone belt; Lower level Carboniferous limestone areas; (high level limestone is peat covered and in group (4)). Mostly replanting; some afforestation in Wolds valleys.

Main site factors. Dominant factor is highly calcareous soil, often with bed rock only a foot or two below surface. The Magnesian limestone belt is in the penumbra of the smoke pollution from the coalfields region.

Species to plant. Beech (*Fagus sylvatica*), ash, sycamore, European larch (*Larix decidua*), Corsican pine.

Avoid or use with great care—all other species, especially conifers. Large areas of Scots pine put on Corallian limestone in the early plantings in Allerston forest developed severe chlorosis and die-back as they reached pole size. Now underplanted with beech. Chlorosis and die-back of conifers frequent in the Wolds.

6. *The Yorkshire Coalfield.* Replanting woodlands and afforestation of opencast areas.

Main site factors. The dominating site factor is the high level of atmospheric pollution. Soils, elevations, and shelter very variable. Human trespass and fire danger very high. Compacted soils and danger of erosion on restored opencast sites.

Species to plant. Sycamore, beech, Corsican pine, Japanese or Hybrid larch. Experiment with Lodgepole pine.

Avoid completely all conifers other than above. Beware of the temptation of putting in one of the above 'pollution resistant' species in a site which is too infertile, or unsuitable for the species in some other way.

7. *South Pennines.* The high-level, narrow millstone grit ridge between the coalfields and industrial regions of Lancashire and Yorkshire; attempts at afforestation of catchment areas.

Main site factors. The dominating factor is very high atmospheric pollution combined with high elevation—in its extreme form an absolutely fatal combination. Soils poor, leached or deep peat; *Molinia*, *Eriophorum*, or heather.

Species to plant. In worst areas NONE. Pilot plot experiments indicate that Lodgepole pine and Japanese larch have some hope of survival, but profitable forestry in the higher parts of this region must be regarded as impossible. In sheltered valleys, conditions are similar to those of the coalfield.

PRIVATE WOODLANDS

Extent and condition of woods. Census figures, adjusted to bring them up to September 1959, indicate that in Yorkshire the total area of privately owned woodlands of over 5 acres is approximately 120,000 acres. In addition there is about 10,000 acres of small woods of 1 to under 5 acres in area. Of the total, a little over two-thirds by area is more or less productive, and rather less than one-third is unproductive.

The productive woodlands are virtually all managed on the high forest system,

and the total area on this system consists of about one-quarter conifers, one-quarter mixed, and one-half broadleaved stands.

The distribution of age classes in privately owned high forest in the North Riding is shown in Fig. 1. The general pattern of age-class distribution in the other two Ridings is closely similar. About 30 per cent. of the total area of broadleaved high forest is classed as uneven aged, against 12 per cent. in mixed stands and only 3 per cent. in coniferous stands. This reflects the greater facility with which broadleaved species regenerate naturally.

The relative importance of the different species is shown in Table V and the swing to planting more conifers in recent years is apparent in Fig. 1.

TABLE VII. *Yorkshire. Private woodlands in the dedication and approved woodlands schemes*

(N.E. (England) Conservancy only. As at November 1959.)

Scheme		*No. of estates*	*Total area in acres*
Dedication	Fully completed	107	33,802
	Covenant under preparation	6	498
	Total	113	34,300
Approved woodlands		53	7,882
Total, working to standard plan		166	42,182

The dedication and approved woodlands schemes. From Table VII it is seen that 42,000 acres of woodland on 166 estates is now managed under standard plans of operation. This represents about 35 per cent. of the grand total of privately owned woodland in Yorkshire, a proportion which compares very favourably indeed with the standard for the country as a whole.

General standard of management. There are relatively few estates in Yorkshire with over 1,500 acres of woodland. There are, however, a very considerable number with between 250 and 1,500 acres, and the majority of such estates, and many of those which are smaller, practice good forestry. The standard of work has unquestionably risen greatly during the past 10 years, and the improvement shows every sign of spreading and progressing steadily in the future.

Clear-felling followed by straight replanting is the normal method of regeneration in private estates, and in general very little systematic use is made of cover for shelter to young crops. Underplanting is rare—though there are one or two very successful examples available—and natural regeneration appears more often by accident than design.

Supervision and labour. The foresters and supervising woodmen employed by private estates are most variable in training, quality, and function. A few are highly skilled and competent individuals, but there are many estates which do not employ a suitably trained forester, and work suffers accordingly.

The forest worker standard on private estates in Yorkshire is also most variable, being in general too low. Wages and conditions of service are frequently inadequate and piece work is very rare.

TABLE VIII. *Yorkshire. Forestry Commission Land. Summary of land utilization by counties*

(As at September 1959. Areas in acres.)

Conservancy	*County*	*Plantations*	*Land in hand awaiting*		*Total land now classed as woodland for Census purposes* Cols. (3) & (4)	*Total land awaiting replanting or afforestation* Cols. (4) & (5)	*Total 'Forest Land', i.e. planted or to be planted* Cols. (3), (4), & (5)
			Replanting	*Afforestation*			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
N.E. (E.)	N. Riding	33,680	6,251	5,714	39,931	11,965	45,645
	E. Riding	2,134	441	127	2,575	568	2,702
	W. Riding	4,136	3,248	3,210	7,384	6,458	10,594
	Total N.E. (E.)	39,950	9,940	9,051	49,890	18,991	58,941
N.W. (E.)	W. Riding	3,337	90	536	3,427	626	3,963
	Total 'Forest Land'	43,287	10,030	9,587	53,317	19,617	62,904
All Yorkshire	Agricultural, Nurseries, Requisitioned, &c.						13,465
	Grand Total Forestry Commission Land						76,369

'Forest land' as applied to Forestry Commission property implies land carrying, or destined to carry, a forest crop.

FORESTRY COMMISSION PLANTATIONS

Afforestation and replanting. When one turns to the management and silvicultural aspects of the Forestry Commission's work in Yorkshire it is desirable to emphasize at once the fundamental differences of the basic problems and the techniques involved respectively in the afforestation of bareland and the replanting of woodland.

Space does not permit a complete coverage of all the details and individual variations encountered in the State forests of the county, so a generalized comparison is presented in Table IX.

Nearly all the early work of the Commission in Yorkshire was afforestation of moorland in the North Yorkshire Moors area, but after the beginning of the new drive for forestry expansion following the Second World War, land was acquired more freely and much more widely, and old woodland areas, previously in private ownership, were taken over for replanting in areas scattered throughout the county. The relative importance of the two types of planting in our post-war programmes is indicated in the following figures—areas in acres.

	Afforestation	*Replanting*
Planted by F.C. in 13 seasons 1946–7 to 1958–9 . .	12,500	9,000
In hand to plant as at September 1959	10,000	9,500

The quality classes and production of all the main species in Allerston District, i.e. Scots and Corsican pine, Sitka and Norway spruce, Japanese and Hybrid larch, and Douglas fir, are at or below the middle of quality range given in the standard yield tables. On the plateau sites some of the earlier planted crops were in check for many years, and this results in very low quality class assessment. The average annual increment over all plantations in Allerston is probably between 75 and 95 cu. ft. per acre but no comprehensive increment assessments exist. This

TABLE IX. *Afforestation of bareland versus replanting of woodlands relative differences—generalized*

Item	*Afforestation*	*Replanting*
Land type	Bare moorland; bracken banks; derelict fields	Old woodlands
Size of blocks	Large; concentrated	Small; scattered
Suitable species	Few. Conifers only	Wide choice available, both conifers and broadleaved
Preparation and planting	Nearly all ploughed. No scrub clearance. Very cheap	Ploughing rarely possible. Often heavy scrub clearance. Often very expensive
Fencing	Usually well below 1 chain per acre	Often 2 to 3 chains per acre
Weeding	Negligible	Costly and tedious
Total cost to establishment*	Low; say £30–40 per acre	High; say £45–60 per acre
Potential production	Rather low, usually Q-Class IV/V Average M.A.I. 75–95 h. ft.	Often high, Q-Class II/III Average M.A.I. 110–50 h. ft.

* excluding overheads

shortcoming will be rectified when a new working plan is prepared during the next 2 years.

In much of the Plain of York and in the Lower Foothills regions, growth averages at least one quality class higher than on the Upland Heaths. Quality class I and I/II pine and European larch is frequent. Hardwoods, spruces, and Douglas fir would average one half to one quality class lower on the respective standard yield table scales.

The total produce from thinnings from State forests in Yorkshire during the year ending September 1959 was 316,000 cu. ft. By 1965 the annual yield of State forests should be 500,000 cu. ft., and by 1975 somewhere about the one million mark. Most of the current yield of thinning is sold standing.

Cultural Operations

Ground preparation. Clearance of scrub is a very costly operation on old woodland areas on the plains and foothills regions. The worst type is birch and rhododendron scrub thicket, which may be prohibitive when it costs £50 per acre to clear. Dozer rakes have been tried with only moderate success. The Roadless

TABLE X. *Yorkshire. Forestry Commission Land. Details of land utilization by districts and forests*

(As at September 1959. Areas in acres.)

Forest Districts N.E. (E.) Conservancy	*Forest*	*Area of acquired plantations*	*Area planted by Forestry Commission*	*Area awaiting planting*	*Agricultural nurseries unplantable and other*	*Total*
Allerston	Langdale	19	6,101	585	8,015	14,810
	Allerston	140	9,415	287	757	10,599
	Rosedale	403	6,914	1,092	3,116	11,525
	Total	562	22,520	1,964	11,888	36,934
Cleveland	Cleveland	133	2,013	1,889	62	4,097
	Hambleton	85	1,687	2,317	190	4,279
	Rievaulx	280	420	2,410	205	3,315
	Ampleforth	212	3,248	2,034	265	5,759
	Total	710	7,368	8,650	722	17,450
Dales	Arkengarthdale	..	1,120	343	136	1,599
	Jervaulx	119	805	696	4	1,624
	York (Part)	127	454	481	11	1,073
	Fountains	166	270	947	4	1,387
	Knaresborough	5	563	110	2	680
	Skipton	3	..	161	..	164
	Bingley	..	40	17	..	57
	Tong Woods	..	159	36	..	195
	Total	420	3,411	2,791	157	6,779
South Yorks.	Selby	178	864	699	2	1,743
	Doncaster	265	498	603	7	1,373
	Cawthorne	105	100	484	..	689
	Wharncliffe	40	600	480	61	1,181
	Holmfirth	85	88	629	52	904
	Hebden Royd	2	..	2,083	111	2,196
	Total	675	2,150	5,028	233	8,086
East Riding	Scardale	73	676	63	289	1,101
	Londesborough	82	500	350	16	948
	York (Part)	238	565	155	35	993
	Total	393	1,741	568	340	3,042
Yorkshire in N.E. (E.) Conservancy		2,760	37,190	18,991	13,340	72,281
N.W. (E.) Conservancy	Bowland (Part)	..	426	249	..	675
	Gisburn	..	2,737	287	125	3,149
	Sherwood (Part)	..	174	90	..	264
Yorkshire in N.W. (E.) Conservancy		..	3,337	626	125	4,088
ALL YORKSHIRE		2,760	40,527	19,617	13,465	76,369

Brushcutter has proved itself a very valuable machine in clearance of gorse, dense brambles, and light scrub.

The present policy is to cultivate the soil prior to planting whenever this is at all feasible. The checking and poor growth of the early planting on Upland Heaths was due to inadequate soil preparation. Since 1943 R.L.R. ploughing has been standard practice on all moorland afforestation. Parkgate tine-ploughs are now replacing the R.L.R. Without deep ploughing there can be little success with the afforestation of Upland Heaths.

For afforestation of chalk grassland, full and fairly deep ploughing is considered best.

Where stumps are not too tough or thick on the ground, old woodlands are sometimes ploughed with a mounted Fisher Humphrey plough, and satisfactory results on bracken have been achieved with a rotovator, which is, however, useless on grassy areas. Suitable treatment of land covered with creeping soft grass has not yet been evolved.

Brashing. In the pressure of post-war arrears of work, line brashing was resorted to, leaving alternate rows between trees untouched, but now the policy is '70 per cent. brashing', in which the object is to brash every tree that is likely to come out as produce and leave untouched every stem unlikely ever to be utilized. All brashing is by saw.

Thinning. Only in the Allerston District are there large areas of State forests in the thinning stage. Since 1947 the degree of thinning has been relatively heavy, probably averaging one class heavier than that on which the standard yield tables are based. Measurements in a large number of thinning plots in the Dalby area show that relative to the standard yield tables quality classes, our crops have about 80 per cent. of the 'normal' number of stems to the acre, higher average diameters and volumes per tree, and slightly lower volumes per acre and current annual increments. This applies to all species.

Nurseries. There are major nurseries in York, Allerston, and Langdale Forests with a total area of 99 acres (at September 1959).

The nurseries are mostly of the heathland or woodland type and they are highly productive, producing considerably more plants than are required for the Yorkshire State forests planting programme.

FOREST RESEARCH IN YORKSHIRE

The Research Branch of the Forestry Commission have two experimental areas in Yorkshire which are of much more than purely local interest. The oldest, best-known, and most important series is the Allerston group of investigations into the afforestation of upland heath—a classical example of British forest research which has very recently been fully written up by Zehetmayr (1960). From the earliest days up to the time of his death, Lord Robinson had a very special interest in the afforestation of Allerston and in the development of research in that area.

A much more recent and more modest series of experiments are the pilot plots on the South Pennines, designed to discover whether it is possible to afforest satisfactorily the pollution-cursed highlands of this region.

Research on afforestation of Upland Heaths

Afforestation in Allerston District on the North York Moors near Pickering and Scarborough has been continuous since 1921 and the results now form the largest expanse of plantations on 'Upland Heath' in Britain, while the experimental areas, with a total of well over 200 field experiments, comprise much the largest concentration of research planting. In addition to the work carried out

directly by the Research Branch, much of the field work for more fundamental research sponsored by the Forestry Commission and carried out by workers from Oxford, such as Dimbleby, Leyton, and Rennie, has been located in these forests. Much literature has resulted; for details see Zehetmayr.

The Allerston plantings of the earliest years were concentrated in the dales and on the more favourable slopes, but as the work spread to the poor heathland of the plateau, trouble began, with very serious and mounting difficulties in getting establishment.

In 1928 the rate of planting was drastically cut and an intensive research programme was initiated, with Wykeham and Harewood Dale chosen as examples of ploughable and unploughable ground respectively. By 1931 satisfactory 'medium' ploughing gear had been evolved and by 1936 the supreme importance of deep cultivation as a prelude to afforestation of upland heath had been proved decisively. The 'R.L.R.' ploughs started operating in 1943.

At Wykeham some 70 experiments on 130 acres were initiated from 1928 to 1941. The Harwood Dale area occupies 60 acres with 40 experiments planted from 1932 to 1942. Broxa, with almost identical site conditions to Wykeham, has been used for follow-up experiments based on Wykeham findings and indications. Work started in 1941 and is still continuing, with over 90 experiments on 220 acres to date. There are also a few experiments on Rosedale Forest.

The facts established by the Research Branch plots in Allerston District are the foundation of all the modern techniques used for afforestation of Upland Heaths in Yorkshire and indeed in all parts of Britain. As well as establishing the basic principles of deep soil cultivation, the experiments have provided invaluable information on mixtures, manurial treatment, root development, and heath and nurseries. Quite recently special attention is being focused on the problem of second rotation crops.

Research on afforestation on the South Pennines

In the hunt to find land for planting to meet the big post-war programme laid down in 1945, attention was directed to the great water-catchment region of the Southern Pennines, where many water authorities were interested in getting stock removed and in the possibility of having afforested catchment grounds.

It was known that atmospheric pollution was severe and a very serious deterrent to economic forestry but little solid fact was available. To establish the facts, a series of afforestation pilot plots were laid down in 1951–3 in the Widdop area of the Halifax Waterworks gathering grounds, with further plots on newly leased Forestry Commission land in Hebden Royd Forest in 1957–9.

It will be many years before final conclusions can be drawn, and in the meantime there will be no Conservancy planting programme in the South Pennines, except on sites exceptionally well sheltered or at lower elevations.

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FIG. 2. Bickley, Langdale Forest. General view of the Tabular Hills from Jerry Noddle, looking east towards Hackness. Forest workers holdings in foreground, with plantations on the steep slopes. On plateau, farms on good and plantations on poor soils.

FIG. 3. Staindale, Allerston Forest. Hybrid larch, 28 years old. Photographed in 1952, since when increment has fallen sharply. Note typical thick mat of *Deschampsia flexuosa* which may be a critical factor in low rainfall areas.

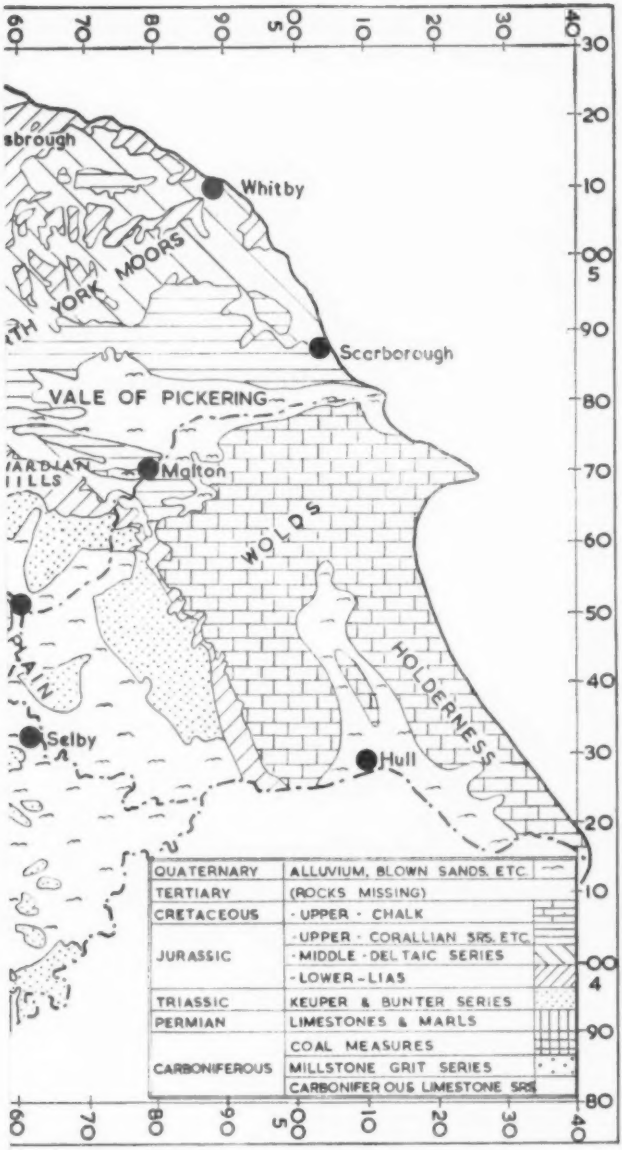
PLATE VI

By courtesy, Lord Bolton.

FIG. 4. Bolton Hall, Wensleydale. Group of very large old sycamore. Many have curly grain and one was sold recently for nearly £500.

FIG. 5. The Park, Harewood. Landscaped by Capability Brown. The photograph taken from the front of the house shows only one segment of the wide, sweeping panorama of lake and hill, so skilfully set off and enhanced by Brown's woodland belts and plantations.

PLATE VII



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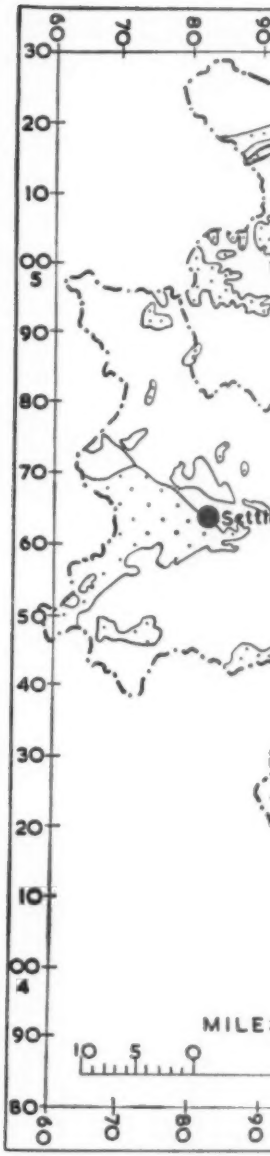

FIG. 6.

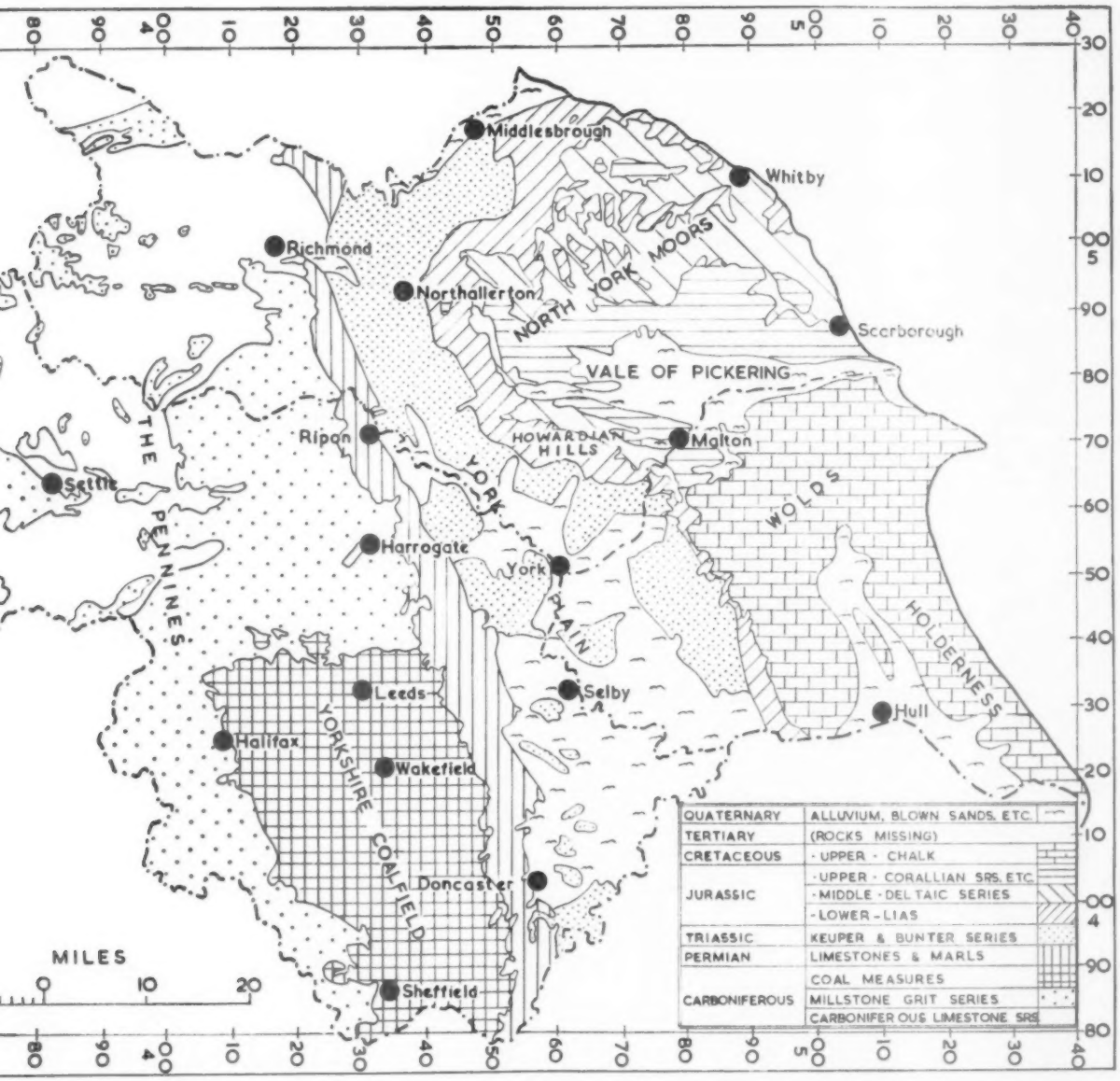

FIG. 6. Yorkshire Geology, Boulder clay, Moraines &c. omitted. The marginal numbers are National Grid references

THE INVERNESS EXCURSION: THE SCOTS PINE

ONE tree—the Scots pine—dominated the 1959 excursion to the north of Scotland. Over ninety members attended the meeting which was admirably organized by Mr. J. A. Dickson. Glen Affric and Guisachan Forests, the Seafield Estate, the Black Isle, Lethen, Cawdor, and Culbin were all visited. Fortunately Professor Steven, fit again after his illness last year, was able to be with us throughout. He had important things to say and said them very convincingly. There were four principal speakers at the evening discussion and extracts from their prepared notes form the backbone of this account. For a fuller record of the meeting we invite reference to Mr. W. MacF. Robertson's account in the *Empire Forestry Review* for December 1959.

THE NATIVE PINEWOODS

The following are extracts from Professor Steven's talk on the 'Native Pinewoods and their Management'.

I have stated recently[1] what, in my opinion, is the special significance of these woodlands, and I shall recapitulate briefly:

(*a*) They are one of the most interesting survivals of our native vegetation and have a distinctive fauna as well as a characteristic flora. Most civilized countries now ensure the perpetuation of such on an adequate scale.

(*b*) They contain a range of distinctive strains of Scots pine. There are, for example, a number of habit types as you have seen and the available evidence, while not conclusive, suggests that most are genetically controlled. Some of these morphological variants are obviously desirable silviculturally, some are not, but the latter may have as yet unrecognized desirable qualities of another kind. The wide range of morphological variations, which may be paralleled by physiological differences, suggests that past destructive exploitation has probably not eliminated the most desirable variants, although it may have altered their proportion. The most important characteristic of these strains, however, is that they have persisted for over nine millenia and today they remain healthy to advanced ages, much beyond that required in normal forest management, and on the poorest sites. Moreover, some of the native pinewoods are in the west and have persisted and are still growing under extreme oceanic climatic conditions where ordinary Scots pine often fails or does very badly. So far as the perpetuation of these strains is concerned, one could argue that if one took an adequate range of scion material and maintained it in tree banks, one could dispense with the native pinewoods. While the taking of scion material has been rightly done already by the Forestry Commission and should be extended, it is almost certain that one will want to go back to the woodlands for material for checking and study.

(*c*) Many of these surviving woodlands are growing under adverse conditions and thus they provide opportunities for investigation into both the potentialities and limitations of this species. This advantage should not be lightly thrown away.

(*d*) Particularly in the most westerly of these woodlands, there are both birchwoods and pinewoods, and there are examples of the alternation of such. The influence of these

[1] H. M. Steven, 'The Native Pinewoods of Scotland and their Significance for Current Forestry Practice', *The Advancement of Science*, XV, No. 59, 1958, p. 340.

communities on soil conditions is a matter of current importance and of controversy, which these woodlands may help to resolve. If one agrees that these woodlands have special significance in these ways, then their management should provide for the following:

1. *Protection*

As they are irreplaceable, there should be special precautions against fire. The areas to be perpetuated should be adequately protected also against grazing damage by domestic and wild animals. The Forestry Commission, the Nature Conservancy, and at least one private owner has already done this.

2. *Maintenance of a range of variants of Scots pine*

The range of the variants is one of the characteristics of these woods and this should be maintained in regeneration and tending procedures. In normal silviculture one would wish to favour, for example, the habit types considered most desirable in the light of present knowledge, and one may reasonably do so up to a point, because past destructive exploitation has probably reduced their proportion, but one should not go as far in that direction as one would do in commercial woodlands under intensive management.

3. A corollary to the previous point is that any seeding and planting within a native pinewood should only be with seed collected within it. In my opinion it is an unforgivable sin to bring other strains into it.

4. *Regeneration*

The management of these woods must above all else be directed not only to their perpetuation but as far as possible to their creation into something like their earlier condition before destructive exploitation took its toll. I think I can best convey to you what I consider should be done by quoting a short passage from 'The Native Pinewoods of Scotland':[1]

'The aim should be say over a century, to build up gradually a reasonable balance of age classes, old and young, so that there will always be a succession of trees of different ages. The structure should be semi-irregular as it is today in some of the larger and better preserved woodlands, a mosaic of groups and stands of varying extent up to a few acres, each consisting of trees of about the same age and together providing a range in age from the youngest to the oldest, but not necessarily a continuous range of age or any mathematical balance in age or size classes, which is unusual in natural pinewoods as a whole. The other native tree species would, of course, continue to play their role in the woodlands, and regeneration by birches and rowan may later lead to the re-occupation of the ground by pine, as in the past. It is believed that such a forest would also preserve its associated natural non-tree flora and fauna, and come closer to what the natural pinewoods were like some two to three centuries ago before heavy exploitation took place.'

From several different points of view, these woodlands would be better perpetuated by natural regeneration. This has been discussed in some detail in the book just referred, but we do not yet know how this can be best done. A new and determined effort should be made to try and solve this problem. It is almost certain, however, that some artificial regeneration will be necessary; past experience suggests that planting rather than seeding will likely be more successful. At least in the most typical parts of the native pinewoods non-indigenous species should not be introduced, because if this was done it would mean that their ecological characteristics would be changed.

[1] By H. M. Steven and A. Carlisle, Oliver and Boyd, Edinburgh and London, 1959.

5. *Tending*

While under and not over stocking is the principal problem in the native pinewoods, there are limited areas where cleaning and thinning are necessary. As in woods generally, the best trees should be favoured, but any examples of the more unusual habit types and other distinctive variants should be retained.

In conclusion, my plea is that because these woodlands are a unique heritage, they should be managed in the special ways I have just outlined to ensure that they will be perpetuated and developed alike for their historical, ecological, and practical forestry importance.

A main object of the visit on 22nd September to the Glen Affric and Guisachan Forests belonging to the Forestry Commission was to study the management of old natural stands of Scots pine. In Glen Affric the prescribed treatment for the amenity working circle of 1,900 acres is the removal of from 12½ to 20 per cent. by volume of Scots pine in thinnings and the creation and extension of gaps in the birch. It was suggested and indeed freely admitted that the present management plan, besides inevitably removing more than the increment, would make it necessary to fill up with Scots pine nursery stock from elsewhere, i.e. with Speyside stock raised in the Black Isle nurseries. Authoritative assurance was at once given that this plan would be modified to ensure that any sowing or planting necessary to supplement natural regeneration within a native pine wood would be from seed collected within it. We were assured that Professor Steven's ideas, which were first of all the ideas of a practical forester, would be carried out and that no pressure however heavy would allow us to endanger this heritage. We were only just in time and must act quickly. It was doubtful whether the areas reserved were sufficiently large and this point also would be reconsidered.

SEED PROVENANCE

Mr. M. V. Edwards was unfortunately prevented from coming to the meeting, and his paper 'The formation of Scots pine plantations with particular reference to seed provenance' was read by Mr. R. Lines who also took his place at Findon in the Black Isle on 24th September. In addition to the Provenance plots, afforestation and reforestation of poor upland heaths and comparison of growth of Scots pine on ploughed and unploughed sites were shown. Extracts from Mr. Edwards's paper are given below.

Today, at Findon, we saw an experiment which indicated that pine from very high or very low latitudes will not survive and grow there; that pine from Finland grows slowly and has a nice form with pale coloured stems and needles; but that the best growth, from an all-round point of view, is that of the native provenances. Between these, at least if the seed is collected from good stands, the differences are not very great. In other experiments, examples of Swedish and Norwegian provenances can be found and like the Finnish ones are of nice form, but they are slower growing and tend to a yellowing of the needles which makes them look unhealthy.

The conclusion to be drawn from all these experiments, of which the oldest have now reached their 30th year, is that home seed makes the best plantations.

Turning now to differences within the range of home collected seed, we saw that as yet there is no significant difference in growth at Findon, but there are signs that the East

England provenance is drawing ahead in productive capacity and that the Strathconon provenance is gaining superiority in form.

In a small experiment at Roseisle Forest, Darnaway provenance is significantly tallest, but the trees are coarse. Loch Maree and Abernethy trees are intermediate, and a Glen Moriston provenance is the straightest and finest branched. That was the result at the age of 18 years. In another experiment at the same forest, at 13 years, Darnaway, Achnashellach and a German provenance were taller than a number of other Scottish plots, but the form of all the trees, which were planted in groups, was bad. (In both these experiments a Norwegian provenance virtually failed.)

At Culbin, Cawdor, and Darnaway provenances are equal (and better than an East Prussian lot) in size and quality at 26 years of age.

The most detailed comparison of seed from home sources was reported, as far as the nursery stage is concerned, in the Forestry Commission's Annual Research Report for 1954. This experiment showed a high correlation between the size of the seedlings and the weight of the seed, and the seed weight was correlated with the elevation of the parent stands, which were all in the East Conservancy of Scotland. After 3 years in the forest there were no great differences in either survival, height growth, or any other characteristics, but these will no doubt begin to develop differently on the three sites where the experiments are planted, now that the plants are well established. Based on experience in other countries we may expect to find that the provenances which do best are those which are nearest their home, both in a geographic sense and perhaps in respect of environmental conditions, but so far no experiments precise enough to prove this point have been made with our own provenances in this country.

Experiments were commenced in 1929 to try and find a race of Scots pine, in the words of Professor Anderson, 'suitable for planting on peaty moraines in wet districts'. These collections, when planted at Inchnacardoch Forest, both on moraines above the Lon Mor and on the riverine deposits in the valley, have tended in general to repeat the results that I have already described, but differences attributable to provenance are less than those attributable to site differences, because in both cases the experimental plots are situated on variable ground.

The Achnashellach provenance has done well in both Scotland and in Denmark and it has attained some reputation as an outstanding seed source in both places. It may be noted that at Achnashellach itself there is a marked difference in the behaviour of a young crop of this provenance with and without phosphate, and one is left wondering to what extent the trouble with West Coast pine is due to inadequate nutrition on leached impoverished soils, under a high rainfall, or to the fact that Scots pine is there on the extreme maritime fringe of its natural distribution.

In 1949 to 1952 a set of five experiments was planted in Mull, Loch Fyne, Glentrool, and the Lake District on sites similar to those where older crops of pine had failed in the past, with a control in Stirlingshire. Half was ploughed and fertilized and half not. Seed from Altyre in East Scotland, Thetford in East England, Raasay, Mull, and Knapdale in West Scotland as well as Amla and Hedmark in Norway was used. So far the results show that the East Scotland and England provenances have grown best with the west of Scotland lots not far behind and the West Norwegian lot the poorest, but the experiments have not reached the stage at which the older crops died, and it is too early yet to draw conclusions about the provenances best suited to the West Coast.

Note that these remarks apply mainly to Scotland. As shown in the modern Thetford provenance experiment, conditions are different in the southerly parts of England.

Finally, may I remind you that this matter has now passed beyond the bounds of a pure

provenance question. The quality of individual trees in a stand is taken into account by the geneticists, and in conjunction with Tree Seed Associations, stands are being classified as plus, normal, or below normal, and registered for seed collection accordingly. Before long it should be possible to ensure that no seed is collected from stands below normal, and precise comparisons of progenies of the good stands will soon be able to indicate the permissible limits for moving plants from the regions whence the seed was obtained. Until this information is available, we should do all in our power to collect seed from good stands in our own neighbourhood and to use the plants in similar localities.

MANAGEMENT AND UTILIZATION OF SCOTS PINE

The following refers to the Strathspey Estate (The Countess of Seafield) visited on 23rd September, the Lethen Woodlands (Major Brodie) visited on 25th September, and to talks by Major Brodie and by Mr. Riddoch.

The Strathspey Estate is situated in the heart of the Scots pine country. Some 38,000 acres are now under management lying mainly between 600 and 1,250 feet above sea-level. The rainfall is between 30 and 32 inches and winter conditions are severe. Planting started 200 years ago and was continued with vigour by successive Earls of Seafield down to the 1880's. Little of this series of plantings survived two world wars but replanting of Scots pine or regeneration by natural methods was continued after both wars. Only Scots pine seed obtained from their own trees is used and recently a seed orchard has been established on the estate. It has been the standard practice at Strathspey to rely on natural suppression to reduce the density of stands up to 50 or 60 years of age and until thinnings are big enough to pay for the cost of removal. We are indebted to Professor Steven for the following note written from observations made by him in Curr Wood.

The discussion on the lack or inadequacy of thinning in this and other woods in Strathspey indicates that some at least of the party feel that too little attention has been paid to economic considerations. Taking the position until today, however, there is no doubt at all that forestry has been most profitable on this estate and indeed has been its greatest financial asset. I understand that the great afforestation carried out last century was done largely on borrowed money and that these mortgages have long since been paid off and in addition large sums were obtained from the sale of timber for many other purposes. One of the advantages of forest crops is that, provided one need not obtain revenue annually, one can sell during periods favourable as regards price and demand. This estate is an extreme example of this; a large proportion of the timber sold this century was during and immediately after the two world wars.

The principal reason why little thinning was done between the two wars was the very low timber prices during that period. A detailed pitwood utilization experiment carried out in the mid-thirties across the road under the auspices of the Home-Grown Timber Advisory Committee showed that only between one and two pence per hoppus foot was left for the cost of the standing timber. Since the war, priority has rightly been given to restocking the large areas felled in the last war and up to date 7,000 acres or about half the area cleared have been replanted during the past 10 years.

The cost of planting on this estate in the present as in the past has been very low, and the areas of successful natural regeneration have been obtained at practically no cost. It is true that in addition thinnings could have been marked and sold since the war with advantage had there been a larger staff, but it should be remembered that the woodlands

have been run with a very small woodland staff and therefore the overheads have also been very small. In consequence forestry on this estate has indeed been very profitable in the way it has been practised, that is extensively.

The much smaller Lethen Woodlands (2,534 acres) have a similar history of continuous management to Strathspey but present ideas about thinning are different. A summary of Major Brodie's talk on the 'Management of Scots Pine plantations' is given below.

Scots pine can be contrasted with most other conifers which we grow in this country in various respects, and I thought that I might direct attention to four special characteristics and then show how I think they should be allowed to influence management.

1. Scots pine produces less and takes longer to do it than any other of our conifers, with the exception of European larch.
2. Scots pine is a keen light-demander; again with the exception of larch and possibly Corsican pine, it is probably the greediest light-demander of our conifers.
3. Timber merchants who have to do with Scots pine lay more stress on the *quality* of the knots than they do about the size or number.
4. Scots pine is the only conifer about which we have extensive knowledge of exploitation, and consequently about growing to maturity.

My first point is about low yield and slow growth. To combat this adversity we must:

a. Keep costs down to a minimum at every stage.
b. Counter the effect of accruing compound interest by postponing those operations which are not revenue producing to the latest possible date in the rotation.
c. Bring our crop to an earning stage as soon as possible.
d. Manage the crop so that the highest possible proportion of the yield is in sizes and quality most saleable.

I regard each of these as a test which we must apply to any procedure we propose. The procedure is only sound if it conforms to these standards.

The next characteristic is the demand for light. The deduction to be drawn here is that it is a crime to overcrowd these trees; so we should practice a *rigorous thinning régime*. Heavy thinning produces wider annual rings. But the actual width of the rings is less important than their regularity, therefore having once adopted a heavy thinning régime we must practice it throughout the rotation.

The size-class structure of a stand is influenced by the thinning régime, so from the economic angle it is desirable to start thinning early, for early returns; thin severely to get desirable sized mill-timber quickly and to get as high a proportion as possible of our total yield into this desirable size category.

My next point is about knots. Heavy stocking secures branch suppression, but it is the quality of the knots which matter rather than their actual size or frequency. Bad-quality knots are loose or encased knots, or black knots otherwise called 'powder-knots'. These are caused by the incorporation of unsound or rotten dead branches into the main trunk of the tree. It is no good suppressing or killing off side branches if they are to appear as faulty knots in the timber. As natural pruning is rare in this climate, and artificial too expensive and, as small live knots are acceptable in our timber, we should not worry too much about early branch suppression.

Now I come to my last point. The vast inheritance of information which should be ours, and enable us to solve our main problems. Among these are the problem of black or loose

knots and selection of correct strains to secure natural pruning; the difficulty of disposal of our small-sized thinnings; the significance of the size-class structure of the stand; and the value to us of South African methods of cultivating pine, fresh attention to which has been lately called by Mr. Hiley's new book.[1]

Finally I would like to say that I have been talking about managing Scots pine when it is *growing in captivity*. By the time we have made a plantation of it we are treating it as a domestic crop, and we must therefore manage it as such.

'The Utilization of Scots Pine' was the subject of Mr. Riddoch's paper, a summary of which is given below.

In considering the utilization of Scots pine, notice has to be taken of the faults as well as of the good qualities of the timber. Let me describe the faults first.

Unless this timber is grown on typical Scots pine soil and is of a good strain, the stems often fail to be as straight as they should be. The young tree, if grown too fast, is liable to be bent at the butt end of the stem by snow or by heavy weeds. This is often seen when Scots pine has been planted on spruce ground. Even when the trees are too big for snow or weed damage, they do not grow as straight as they should. They are very liable to damage by the Pine Shoot Beetle (*Myelophilus*) with subsequent defects in the straightness of the stem. This forces us to cross cut the stems to short lengths and reduces the value.

Scots pine sometimes tends to have large knots and what is worse, the knots are frequently loose or rotten. We usually call these black knots. The pruning by a suitable saw of branches which may at a later stage cause black knots, seems to be the most satisfactory method which is presently known of dealing with the problem. Any forester who can tell us how to grow Scots pine with only a few small black knots as they do in northern Europe will deserve the highest honour.

Scots pine is the only common conifer in this country which is damaged by red squirrels. If a squirrel scrapes off the young bark, a wound is made which never disappears even when there is little outward sign of the trouble. The numbers of red squirrel are increasing and we shall have to take care that there is not a plague of them as there was at the end of the last century and the first 20 years of this one. The trouble was especially severe throughout northern Scotland where so much Scots pine is grown.

Scots pine is easily affected by blue stain, especially when the weather is warm and damp. If we are to avoid this defect it must be put under cover as soon as it is dry. Sometimes this is necessary before it is dry.

The wetter weather of our west coast makes proper seasoning difficult. Kiln drying does not always overcome the trouble, as it is sometimes difficult to prevent resinous knots becoming unsightly by weeping.

Due to the resinous nature of the wood it is not so popular as spruce where manufacturing processes necessitate mechanical grinding.

Now for the good points.

It is easily grown and therefore cheap. It is strong and tough and holds nails well. It is light and does not warp easily. Its sapwood absorbs preservative better than any other common softwood and it can, therefore, be made to last longer than most timbers at small expense. Owing to the habit in some races of dropping its branches, it can develop a stem of which the outside wood is free from knots. If enough of this clean timber can be collected it can be sold in the same market as Parana pine or other similar cheap, clean wood.

The uses to which Scots pine is usually put in this country are the following:

Young trees or the tops of older trees. Mining timber and fabricated board.

[1] *Conifers. South African Methods of Cultivation.* Faber & Faber, 1959.

Medium-sized trees. Boxes, crates, fencing, and telegraph and transmission poles (if preserved).

Heavier trees. Railway sleepers and wagon wood and building timber.

The short lengths and wide widths which are required for railway sleepers and wagon bottoms, along with the capacity to absorb preservative, made Scots pine eminently suitable for railway work. I am sorry to say that the introduction of steel wagons and proposed changes in methods of laying and types of rails seem to indicate a serious lessening in the use of short-length broad timbers. This will mean that more Scots pine must be used in general building where short lengths are not popular.

In order to assist those responsible for the proper manufacture and marketing of Scots pine in this country, may I ask as earnestly as I can that foresters grow this excellent timber as straight as possible and with as few large and black loose knots as possible. If this can be done, Scots pine may well regain the popularity which is presently being lost to Norway spruce.

GENERAL

Other features of the meeting were the paper read by Mr. R. Miles on 'Forestry and Landscape in the Exmoor National Park' printed in this number, and the visits to Culbin and Cawdor on the final afternoon.

At Culbin the problems of afforestation have been mainly overcome and the problem that remains is the maintenance of a healthy forest in perpetuity. This is under investigation by the Research Branch of the Forestry Commission and by the Macaulay Institute for Soil Research.

Cawdor Big Wood (747 acres) has been under the management of the Forest Department of the University of Edinburgh since 1954, and Professor Anderson and Dr. Mutch met members there and explained the growing-stock objective which is the establishment of an irregular stand structure by a method of mixing groups of about ¼ acre using sessile oak, European larch, and Scots pine as main canopy species with beech, sycamore, silver fir, and hemlock in the middle canopy and hazel, holly, &c., in the lower canopy. Irregularity to be increased by introducing occasional groups of other species, e.g. alder, ash, lime, Norway maple, and Douglas fir.

CONCLUSION

This was by general consent a very good meeting. The arrangements were excellent and the Society thanks all who were concerned with their preparation and all who shared in putting them into effect. The extra day given and the slightly more leisurely *tempo* of the proceedings were, we think, both appreciated.

This account may be criticized for giving main attention to the four papers read at the meeting and insufficient to the woods seen and to the contributions made by others in the forest and at the discussion. This is to some extent inevitable in an account where space is limited and because of difficulties in recording the spoken word. It will, however, hardly be disputed that, in spite of the valuable contributions made by Professor Steven and others, there was still a vast amount to be said about Scots pine throughout Britain which was not said and which ought to have been said particularly by younger members with practical experience in growing and using the tree. Until the opportunity is taken for a free and wide expression of views at these meetings, we shall not get the full benefit from them.

REVIEWS

F. C. Hummel, G. M. L. Locke, J. N. R. Jeffers, and J. M. Christie. *Code of Sample Plot Procedure*, Forestry Commission Bulletin No. 31. London: Her Majesty's Stationery Office, 1959. 15*s.* net.

Review by H. G. Champion

FOR some years we have been awaiting a publication on this subject to bring up to date the account by J. Macdonald that appeared no less than 28 years ago in the *Empire Forestry Journal* (vol. x, 1931, pp. 241–58). We are now provided with an authoritative account of the present standardized procedure for measuring sample plots, in the preparation of which all parties concerned both in field and office have co-operated. This bulletin is somewhat unusual in that the text occupies a mere 19 pages, whilst the Appendices, 14 of them, run to 90! However, nearly half this total is devoted to the fully worked out example without which all such codes never fail to include ambiguities and opportunities for going wrong. Being relevant and helpful, the inclusion of these appendices is wise, and among them Appendix X giving formulae, conversion tables, &c., and Appendix XII summarizing the changes from the older procedure, may be particularized. Two major changes in the field work are the adoption of Hoppus feet in place of cubic feet true measure, and the substitution of an objective method for determining the trees to be taken as samples—all measured standing as no thinnings are now acceptable as samples. In the compilations, graphing against basal area instead of girth, and the calculation of crop volume from the Volume/Basal area line without grouping, in place of from the Volume/Girth line by groups, constitute the biggest changes. There are sound reasons for all these changes though something is lost as well as gained in the case of the adoption of Hoppus measure. A further point worth noting is that top height, in accordance with the now general practice, refers to a specified number (here 100 per acre) of the largest trees in the crop, instead of a more or less arbitrary and varying number falling in the top group under the Block method of grouping.

One might well wonder why the laudable aim to make the whole procedure as objective as possible has been taken thus far but not further, though of course the bulletin is concerned with actual practice and not the reasons for it. The measuring party is allowed (p. 29) to use numerical guides to 'supplement' the definitions of thinning grades based on tree classification and to follow such uncertain directions as to take 'some' trees of a given class. It seems that having marked a thinning more or less subjectively, one might apply one of these numerical checks and if any considerable discrepancy is revealed, select a few more or less of the marked trees to take out. Some Continental foresters have even attempted to systematise the difficult task of marking uniformly in each part of a plot—is this practicable?

It is rather disappointing to find no mention of laying out replications in comparative thinning studies such as the classic set at Bowmont, and still more so, no reminder that a conclusive answer is unobtainable in a set of plots unless the optimum is exceeded by a good margin. The older work has been so deficient in this respect that the point surely needs stressing beyond the provision of an E-Grade. The absence of any directions for the handling of mixtures is noteworthy: surely it is time we began to take this problem up seriously, even if under U.K. conditions we may at least defer the still more difficult one of uneven-aged (and at the same time usually mixed) crops.

In conclusion, another word of commendation, in that for the definitions of the terms

listed in Appendix XIV, the *British Commonwealth Forestry Terminology* has been taken as guide. The reviewer does not, however, think that the changed wording adopted for 'Stop' and 'Surround' are as satisfactory as the originals, and surely 'Thinning Cycle' is preferable to, and much more widely used than the clumsy 'Thinning periodicity'.

OLOF F. S. TAMM. *Studier över klimatets humiditet i Sverige. (Studies on the humidity of the Swedish climate)*. Skr. K. Skogshögsk. Stockh. No. 32. Pp. 48. 1959.

Review by L. LEYTON

IT has long been recognized that the moisture relations of the environment provide one of the key factors determining plant growth and distribution. Although precipitation is perhaps the most important climatic factor in this respect, its effectiveness as a source of moisture for plants is influenced by other climatic factors governing the amount of water lost by evaporation and transpiration, and by edaphic factors governing availability, amount of storage, and outflow (run off). The direct determination of these quantities, however, is both difficult and laborious. In certain catchment areas hydrologists have measured run off and, from the corresponding precipitation, have often been able to construct water balance sheets for these areas. These investigations, together with lysimeter studies, have provided much of our basic quantitative data on moisture régimes in particular areas, but in view of their restricted distribution and limited extrapolation to other areas, other approaches have been tried. For example, attempts have been made to express the moisture status or humidity of an environment in terms of more readily measured climatic factors. Since the turn of the century numerous empirical expressions have been suggested; only during the last decade or so, however, has there been sufficient understanding of the fundamental principles to allow for a more rational approach to the problem. Perhaps one of the best known and most widely used of the modern approaches is that of Penman who, on the basis of the energy requirements for evaporation, has produced an expression for the potential loss of water from an area in terms of the four factors, sunshine, mean wind velocity, mean air temperature, and mean air dew point temperature. Professor Tamm has adopted a somewhat similar but much simpler approach, arguing that in the absence of appreciable differences in altitude, mean air temperature alone usually suffices as a measure of the energy supply to soils and vegetation. From 25 calibrated catchment areas in Sweden outside the mountainous areas, he takes the data on mean annual rainfall (P mm.) and mean annual run off (A mm.) for the period 1921–50. These data allow for the determination, in each area, of the mean annual loss by evapo-transpiration ($E = P - A$ mm.) which, he shows, is significantly linearly related to the mean annual air temperature (T° C.) of that area as obtained from isothermal maps published by the Swedish Hydrological and Meteorological Institute. The regression equation (1) was $E = 220{\cdot}9 + 30{\cdot}4T$; a similar equation (2) was found when he included a further 53 sources of data, all as before, for forested morainic soils outside the mountainous areas. Although relationships with other factors were investigated (altitude, per cent. area of inland lakes, mean annual precipitation, and certain interactions between these factors), it was found that these had little influence on E, and could therefore be neglected. The statistical calculations did in fact result in a possibly more accurate expression (3), $E = 221{\cdot}5 + 29{\cdot}0T$, but the difference was not considered great enough to justify a departure, at present, from the original expression.

The author then compares these expressions with that previously used by Hesselman for characterizing the Swedish climate and based on de Maronne's index of humidity, $P/T + 10$; this latter is shown to be substantially proportional to P/E and, working on similar lines, he obtains an expression, $H_Q = 29{\cdot}0P/E$ which, he suggests, has certain advantages and

could possibly be used for expressing the humidity status of an area over relatively short periods. Close agreement was also found with Turc's findings, based on precipitation and run-off data from catchments and lysimeters in different parts of the world: although for arid climates, Turc showed that E is a function of both P and T, when T is less than 14° C. and P greater than 500 mm. (as is the case for most of Sweden), his equation reduces to $E = 280+25T$, thus very similar to that of Tamm.

Based on equation (1), an evapo-transpiration map of Sweden has been prepared which compares extremely well with an earlier, less detailed map, prepared directly from catchment data. Values for E vary from 450 mm. in the south-west to 200 mm. in the north-west: from other sources of information, the author assumes a value of 150 mm. for the mountainous areas, farther to the north-west.

A second, more detailed map has been prepared giving isolines for humidity, $P-E$ (so-called $\bar{H}$ values) at 50 mm. intervals. This is based on calculations for 1,172 sites; where the appropriate meteorological parameters were not directly available, they were extrapolated from published isotherms and isohyets. Sweden is divided into 6 regions ranging from a so-called 'sub-arid' region in the south-east with H less than 100 mm. to a 'super-humid' region in the west where H exceeds 600 mm. Values for H ranging largely from 300 to 400 mm. are assumed for the mountainous regions, though it is accepted that actual values may vary considerably, as also in other areas with a broken topography where the isolines can only be considered as approximations. For more than half of Sweden, H lies between 200 and 400 mm. with the best agricultural land between 100 and 200 mm.

No consistent relation was found between the humidity values and the nature of the climate, i.e. whether it was maritime or continental; thus, the generally accepted notion that the more maritime the climate, the greater is the humidity, could not be confirmed. Nor could a clear relationship be established between degree of humidity and the nature of the forest type and of forest growth. Whilst poorly productive pine forest of the *Calluna-Cladina* type was rarely to be found in the high humidity areas (and then only on poor mineral soils), such relationships are generally too complicated to allow for a simple correlation. Thus, though a high humidity would normally be expected to produce better forest growth, it is also closely associated with peat and bog formations which depress tree growth.

Certain readers may criticize the derivation of a climatic 'humidity' factor in terms of precipitation and air temperature only, but there is no doubt that Professor Tamm has made logical use of this concept in characterizing the Swedish climate and the consistency of his findings both in relation to previous experiences in Sweden and to investigations elsewhere are impressive enough to merit some serious attention to his approach. The fact that he deals, not with potential evapo-transpirational losses (which are restricted, among other things, to non-limiting soil water supplies) but with actual losses has certain practical advantages, always assuming, of course, that the sources of his data are of the required reliability. From the climatic point of view the results are of considerable interest, but by themselves they are inadequate for a proper appraisal of forest influences. As the author points out, in the absence of the appropriate information, no distinction can be made between the normal forested moraines and areas cultivated for agricultural crops: whether the difference between these is great enough to be of significance is still a matter of some controversy.

G. Giordano. *Logging Cableways.* ECE/FAO. Geneva, 1959. 11 × 8½ inches. Price 9*s*.

Review by A. H. Lloyd

THIS report by the Professor of Technology and Forest Exploitation, University of Florence, Italy, on cableways, is published by the 'Joint Committee on Forest Working

Techniques and Training of Forest Workers'. Its object is to discuss the role of cableways in forestry exploitation. Also to describe the main existing types in operation and the problems of installation, and the economics of this method of timber extraction.

The general advantages of cableways are briefly discussed in relation to labour saving, reduction of damage to the standing forests, and also the ability to log areas which would otherwise be economically inaccessible by road or other means. Cableways are shown to be most suited to timber extraction over topographically difficult country, steep hillsides, and the crossing of ravines or swamps. Also for the rapid clearing of timber badly damaged by fire, windbreak, or insect attack. As cableways are practically independent of weather conditions they can usually be operated throughout the year, and also for long hours each day as much of the work is not very strenuous.

In a brief historical review, which follows, it is mentioned that 'light iron wires' were known in Egypt and copper cable in Pompei. This section of the report is, however, not very clear but this may be due to the translation from the original Italian. A long section, of over 70 pages, deals with the 'Statics of Suspended Cables' and includes the statement [sic] 'as there is no interest for the values of the sag of the unloaded cables, formula 22 (or 42 if the sag is inclined) is always applicable with a satisfactory degree of appreciation'.

The section which follows, on the installation and operation of cableways, is much clearer and very useful. The various mechanical devices used in the old Valtellina tricables and other similar systems are clearly described and well illustrated. Some of these methods still exist in Italy and Austria chiefly on permanent sites and for long distance hauls, but are being gradually replaced by more modern Skyline Cranes.

The author has covered a very wide and difficult subject in a report, of 245 pages, which will be particularly useful to forest engineers operating in forests in mountainous country.

KENNETH P. DAVIS with chapters by G. M. BRYAM and W. R. KRUMM. *Forest Fire: Control and Use.* McGraw-Hill Book Co. Inc., London, 95 Farringdon Street, E.C. 4, 1959. 9×6 inches. 584 pp. illustrated. Price 93*s*.

Review by K. W. WILSON

THE publication of this book gives up-to-date coverage of the last major subject in the well-known American Forestry series. Few will disagree with Professor Davis's assertion that considerable contributions to the study of forest fire have been made by the U.S. Forest Service though some may be a little critical of the scant recognition given to workers in other countries, either in his preface or among the 551 references which nevertheless form a useful appendix to the book. Whilst illustrations and examples in the text are drawn from North American sources, the principles and approach are capable of the widest application. Therefore, this treatment which follows fairly closely that given in Hawley and Stickel's *Forest Protection* (1948) and *Elements of Forest Fire Control*, F.A.O. (1953), will be helpful to all with an interest in the subject, either as students, teachers, or practitioners.

The first part deals with fire effects and behaviour as it is from these that fire control as a land management problem springs. Fire effects on trees, soil, microclimate, and vegetation are fully related as well as their importance as factors promoting change of land use or the continuance of existing vegetational types.

In Chapter 3, 'Combustion of forest fuels', Bryam introduces the general topic of fire behaviour, explains the relationships between temperature, fuel types and characteristics,

topography, fuel water content, and heat transfer and their effects on the pattern, intensity, and rate of spread of fires. This leads to the consideration of the three-dimensional concept of fires and the application of certain principles in atmospheric physics and thermodynamics to an understanding of high-intensity fires. The explanations, whilst not altogether satisfactory, point to a thermodynamical solution being derived after further study though its application in forecasting fire behaviour will present difficulties.

Whether this solution is found or not does not diminish the important effect of weather conditions upon the initiation, development, and suppression of fires. Krumm provides an excellent account of basic meteorology in his chapter on 'Fire Weather' which might best be read before the preceding chapter for his useful explanation of thermal instability.

From forest fuels treated in an earlier chapter as a combustion material in relation to fire behaviour, we pass now to a description and classification of fuels as they are found in the forest. Whilst examples are drawn from North American forest types, the principles of the classification can be applied in any region to guide the evaluation of total energy available, rate of spread, and resistance to control as factors in fire control planning. Fuel-mapping is not a recommended exercise as, under constantly changing conditions, fuel-type maps are hard to maintain in a reliable form.

In view of the increasing interest in Britain and elsewhere in the development and use of fire danger rating in fire control, the comprehensive account given in the final part of this section on Fire Behaviour will be helpful. The Danger Meter, Type 8, as developed in the Southeastern Forest Experiment Station, N. Carolina, is used to illustrate recent trends in methods.

Based on the fundamentals of fire behaviour described so far, Part 2 sets out in considerable detail the principles and practice of fire control; the chapter headings, Prevention of man-caused fires, Hazard reduction, Detection, Fire Suppression methods, and tactics indicating the scope of the treatment. The description of methods and the hand and mechanical equipment suitable for the job is given extensively in 'Control Line Building' and will repay careful study by those in a position to hasten the development of such equipment.

The role of water in suppression methods is then discussed and followed by a description of equipment for water storage, delivery, and methods of use. Here it would have been helpful to have included some treatment of hydraulics in relation to design and layout of pumping equipment. The extensive use of 'wetting agents' in the U.S.A. is reported and a more enthusiastic appraisal of their value is given than in British reports (D.S.I.R. Fire Research, 1952). Fons (1950) reported that in their use in fire suppression savings of 23 per cent. in volume of water required were made, rekindling was reduced by as much as 30 per cent., foaming qualities reduce the run-off of the water, flames are knocked down more quickly and dead fuels remained wet up to 50 per cent. longer.

The last chapter in Part 2 will be useful reading for those responsible for setting-up or operating a fire control organization. Though the dramatized case-histories may not have a wide appeal, they do serve as a sort of 'visual aid' to understanding the problems and practice of fire control in North America. Though effective communications are essential in most aspects of fire control surprisingly little is said on this subject and there are no bibliographical references.

Book prices have risen considerably over the last 20 years and American publications possibly to a greater extent than our own. The cost of this book may deter purchase by potential readers but those who have any interest in the subject will find some way of reading what will be the standard work for many years.

V. Westhoff. *The Vegetation of Scottish Pine Woodlands and Dutch Artificial Coastal Pine Forests; with some remarks on the ecology of* Listera cordata. Acta Botanica Neerlandica, 8, 1959. Pp. 422–48.

Review by A. Carlisle

In this paper the author discusses the significance of the presence of neophytes in the field layer of the pine plantations of the Netherlands, and compares the flora of these plantations with those of both planted and natural pine communities in Scotland.

The coniferous forests of the Netherlands are essentially cultivated forest communities. Plantations of *Pinus silvestris*, *Picea abies*, *Pseudotsuga menziesii*, *Larix leptolepis*, *Pinus nigra*, and, to a lesser extent, other species have been established mainly since the eighteenth century. *P. nigra* has been planted in quantity on the coastal and island sand dunes. Ecologically these forests have not been regarded as separate plant communities, and most of them have been included in the *Querceto–Betuletum* category. During the last hundred years, however, a number of plants characteristic of indigenous conifer woodlands in boreal-montane conditions, have migrated spontaneously into these plantations; for example, *Goodyera repens*, *Linnaea borealis*, *Lycopodium annotinum*, and *Listera cordata*. It is not clear how these plants arrived, but the author disagrees with the view that species such as *Goodyera repens* and *Linnaea borealis* are 'glacial relics'. The autecology of *Listera cordata* is described in detail. This species is generally associated with boreal-montane conditions, and it has been recorded most frequently on moist, acid sites in woodlands, but it has also been observed on moorlands, mountain pastures, and even moist places among sand dunes of low lime content. In the Alps and the mountains of Central Europe it is associated with indigenous *Picea* forest and, to a lesser extent, *Abies-Picea* forest, but farther west, in the Eastern Pyrenees and Scotland, it is associated mainly with *Pinus* forest. In northern Scandinavia it has been recorded in *Alnus* and *Betula* woodland.

In 1956 the author visited pine woodlands in Scotland, at Fochabers and Culbin Sands in Morayshire; Curr Wood, Abernethy, and Rothiemurchus in Inverness-shire; and Beinn Eighe, by Loch Maree in Western Ross. All these woods, with the exception of Culbin Sands, consist of *Pinus silvestris*; the actual woodland examined at Culbin Forest consisted of *P. nigra* sp. *laricio*. It is unfortunate that at Abernethy and Rothiemurchus the sites selected for study were on the shores of Loch Garten and Loch-an-Eilean respectively, as these woods are only partially indigenous, and have been altered by planting. As the author was concerned with the indigenous woodlands, a study of more representative sites nearby would have been more rewarding. Using the Braun-Blanquet scale, the frequencies of species of the field layers of these pine woods were recorded, and it is suggested that the indigenous pine woodlands of the Scottish Highlands resemble the boreal sub-alliance, *Piceion septentrionale*.

Listera cordata was only observed by the author in the Corsican pine woodland on Culbin Sands, although the species had been observed previously at Beinn Eighe by Dr. McVean of the Nature Conservancy. The reviewer, however, has recorded *Listera cordata* in all the localities visited by the author, with the exception of the Fochabers pine wood, and in most of the other indigenous *Pinus silvestris* forests in Scotland. The reviewer found that generally the plants are scattered very thinly throughout the woodlands, and are most frequently associated with tall open *Calluna vulgaris* with a well-developed mat of mosses such as *Hylocomium splendens*, *Pleurozium schreberi*, and *Sphagnum cymbifolium*: *Listera cordata* was never seen in dense shade, and it generally occurs beneath a rather open tree canopy, or at the forest margins.

In the last part of the paper the author describes the flora of the Corsican pine plantations

of Culbin Sands and compares them with three plantations of *Pinus nigra* on the West-frisian Islands, and refers to them as a '*Pinus nigra*+*Pinus sylvestris*—*Listera cordata*—*Pseudoscleropodium purum*' consociation. It is interesting to note that the populations of *Listera cordata* on these Dutch islands are large, there being as many as thousands of individuals per 100 sq. metres. A similar phenomenon was noted by the reviewer in Scotland, where *Linnaea borealis*, so rare in the indigenous pinewoods of the Highlands, is abundant in an old pine plantation in the south-eastern Lowlands; and *Goodyera repens* is more common in the older pine plantations of Deeside than in the indigenous woodlands nearby.

The author considers the future development of the present 'nascent' association of the pine consociation on the Westfrisian Islands, and states that one of the woodlands, growing on dunes of low lime content, may be expected to develop into a well-defined association of the *Piceion septentrionale*.

W. E. Hiley, R. M. Harley, and R. Lehtpere. *An Examination of the Accounts for the years 1955–56, 1956–57, 1957–58.* Dartington Woodlands Ltd., 1959, 4*s.* post free.

Review by A. J. Grayson

THE importance of this latest publication of Accounts for the Dartington woods which deals with the years 1955–6, 1956–7, 1957–8 in some detail, lies in the fact that Mr. Hiley and his colleagues have now produced a review of 11 years of working to the end (30th September) of Forest Year 1958.

The central feature of greatest interest in the Dartington Accounts is the provision for changes in the valuation of the woods (as well as in fixed assets, stocks of plants and converted timber) in the Profit and Loss Account. The cash surplus or deficit in any year involves a quite different appraisal: being 'the increase or decrease during the year in the Company's bank balance which would have been realised if all outstanding debts had been paid and all outstanding credits had been received (after making any necessary provision for bad debts)'. The audited Profit and Loss Account is not presented, but Table 3 headed 'Statistics for Eleven Years' (F.Y.s 1948–58) brings together the most relevant figures on one page and includes figures for profit and for cash surplus.

The distinction between profit and surplus (as also between loss and deficit) relies on the recognition of capital appreciation in the forest, so that, in broad terms, a cash surplus (or deficit) added to a capital appreciation (or depreciation) yields a figure of profit (or loss). Clearly the appraisal of profit in the sense outlined is a most useful and informative measure of the success of an enterprise over a period of years. Another virtue of this method of accountancy is that it tends to even out peaks and troughs in the annual trading account which arise when the amounts of timber cut and sold differ markedly from year to year.

The methods of valuation actually used yield conservative figures so that the evening-out process is not carried as far as may be possible in this direction, though it should be noted that no system can hope to make full allowance for rapid changes which may occur in the sale prices of timber. Mr. Hiley's demonstration of the working of the system of profit and loss accounting which he adopts is invaluable for those concerned with the management of a forest estate within which a periodic assessment of the profitability of its investment is desired.

The examination of the accounts under review is the last for which Mr. Hiley is personally responsible and we are indebted to him for yet another clear and informative exposition of the financial results obtained.

The preparation and analysis of more accounts like these will certainly aid progress in forest economics and hence enable the subject to contribute more fully to successful forest management. In relating the money flows to physical factors over a wide range of activities from Christmas tree growing (an important revenue-producing line at Dartington) to road building, Mr. Hiley has made the whole series of examinations cohere and thus yield a great deal of information. One hopes for the continuation of these examinations of accounts, and the widening use of similar systems, and one looks forward to the emulation of the willingness to publish results which is such a refreshing feature of the Dartington accounts.

OBITUARY

WILLIAM DALLIMORE

WILLIAM DALLIMORE, I.S.O., V.M.H., Keeper of Museums, Royal Botanic Gardens, Kew, from 1925 to 1936, and Honorary Curator, National Pinetum, Bedgebury from 1925 to 1945, the well-known authority on trees and shrubs particularly conifers, died recently at Bidborough, Tonbridge, aged 88.

Dallimore came to Kew in 1891 as a student gardener. He was later in charge of the arboretum and as Keeper of Museums built up the well-known Museum of British forestry. With the late A. B. Jackson he prepared the first edition of the standard *Handbook of Coniferae* in 1923, the third edition of which appeared under Dallimore's guidance in 1948. A smaller book of his, *The Pruning of Trees and Shrubs*, first appeared in 1927.

The decision to form a new pinetum at Bedgebury to supplement that at Kew, which was threatened by industrial expansion and pollution from the air, was taken in 1924 and, in his foreword to the second edition of the Forestry Commission's *Guide to the National Pinetum and Forest Plots at Bedgebury*, in which Dallimore wrote the chapter 'The National Pinetum', Sir Geoffrey Evans wrote in 1955. 'The first plantings were put in hand in 1925 and were carried out by Mr. W. Dallimore. He supervised this work until 1945, and it is almost entirely due to his unfailing zeal that this large collection of conifers has been got together and maintained. . . . When Mr. Dallimore relinquished his post of Honorary Curator, he consented to remain on the Committee as a member, and his valuable advice has therefore been available for the new developments which have become necessary in recent years.' At Bedgebury, Dallimore shares with Sir Arthur Hill the honour of having an avenue named after him.

Dallimore was one of the earliest members of this Society. He served on the Council from 1928 to 1930 and from 1934 to 1935. He was President in 1933. He wrote two papers for *Forestry*. The earlier, 'Aesthetic Considerations in British Forestry', was printed in the very first number in 1927 and, as this is no longer easily available to all, we may appropriately make a few short extracts from it. 'Foreigners', he writes, 'always admire the landscapes of the British Isles. So many of these landscape scenes are of the open park-like type, or, where dense woods appear, they are gradually led up to by tree-dotted fields and commons which effectively mask any harshness that may be present about the outlines of the woods.' He then goes on to describe the beauty of the varied trees through the changing seasons of the year which he says 'make the long journey to some favourite spot inevitable', and adds, 'This is the countryside which we should aim at maintaining in our silvicultural efforts'.

NEWS

Discussion Meeting. Northerwood, 13th–15th November 1959. Following successful meetings held in recent years by the Midland Wood Society, by Dartington Hall in June 1957 (*Forestry*, xxx. 138), and by the Forestry Commission in 1958 (*Forestry*, xxxi. 194–201), the Society accepted responsibility for a meeting in 1959. This was held at Northerwood House, kindly lent for the purpose by the Forestry Commission. The subject for discussion was 'The development of Pulp and Particle Board Industries and their effect on Forest Management with special reference to the Sandwell Reports'.[1]

It will be recalled that Mr. Hiley in his Presidential address to the Society in 1955 (*Forestry*, xxix. 1–3) suggested that the Society should devote more time to discussion, and this suggestion has now been put into effect. As this extension of the Society's activities has been well received, the Council have agreed that other meetings should follow. Possible topics suggested are 'Amenity' or 'Marketing' or 'Labour Costs'.

The proceedings of this first discussion meeting have been published separately and one copy has been sent free to each member. Copies have also been distributed to other interests. Others may obtain copies on application to the Oxford University Press, Amen House, London, E.C. 4, at 5*s.* per copy post free.

Excursion to the Ardennes, 1960. Members will have received details before this appears in print. The party leaves on Sunday 22nd May and returns on Sunday 29th May.

Excursion to Yorkshire, 1960. The annual excursion will be held from 26th to 30th September at Harrogate. The theme of the excursion will be 'The growing of hardwoods in Northern England' and the subject for discussion 'The future of hardwoods in British Forestry'.

New Year Honours. In the 1960 New Year Honours list G. B. Ryle, Director of Forestry for England, was made a C.B.E.

FAO Appointment. Sir Henry Beresford-Peirse, Bt., C.B., has been appointed Deputy Director of the Food and Agriculture Organization's Forestry and Forest Products Division. The appointment took place with effect from 15th January 1960. Sir Henry, who is Deputy Director-General of the Forestry Commission, has been released for service with F.A.O. for 2 years.

Forest Tree Seed Associations in Great Britain. The collection of forest tree seed in the United Kingdom is largely handled by commercial nurserymen, certain private estates, and by the Forestry Commission, and the seed collected has hitherto carried little or no guarantee that it came from a suitable source. A survey of suitable seed sources in Scotland had been undertaken by the Forestry Commission and by 1956 had progressed sufficiently far to enable a Scottish Tree Seed Association to be set up. By 1958 a similar survey in England and Wales was also progressing satisfactorily and it was decided to form a corresponding association for England and Wales. This was inaugurated early in 1959. Some certification of origin is plainly necessary and the first object of the associations is to secure it. The formation of these associations is in keeping with recent thought and is in line with much being done elsewhere and internationally by F.A.O.

While much of what follows is no doubt applicable to both associations, it is in respect of the more recently formed association for England and Wales that we have particularly been asked to call members attention.

The stated objective of this association is 'to improve the quality of all species of forest

[1] Forestry Commission (1959). *Small Pulp Mill Survey, United Kingdom* and *Board Mill Survey, United Kingdom.* H.M.S.O., 4*s.* and 5*s.* respectively.

trees grown in England and Wales by encouraging in all possible ways the use of seed and plants of the best known origins'.

The association will undertake the following tasks on behalf of members:

(*a*) Organize the classification of trees, woods, and plantations for use as approved seed sources and prepare and publish to members a register of approved seed sources.
(*b*) Prepare and publish to members a register of approved seed stores, seed extraction plants, and seed testing facilities.
(*c*) Prepare and publish to members a register of members who are suppliers of seed and plants of approved origin.
(*d*) Issue certificates of origin for seed and plants produced from approved seed sources from time to time in accordance with such terms and conditions as may be issued by the management committee.
(*e*) Disseminate information to members about all aspects of the supply of forest tree seed of the best known origins.
(*f*) Keep in touch as may be desirable with organizations and agencies at home and abroad which are concerned with the supply of forest tree seed and plants and with forest tree breeding.

Progress has been satisfactory to the extent that some 150 seed sources have been classified as suitable for registration and some 120 woodland owners and others have given immediate support by joining. It would seem, however, that others have considered that the association does not concern them because they neither collect seed for their own use nor for sale. This is of course not the case. The association will remove the risk of using seed or raising plants of unknown origin, or of bad parents, or unsuitable for use in a particular climate. See in this respect much of Mr. M. V. Edward's remarks on seed provenance in the account of the Inverness excursion in this number of *Forestry*. The association is non-profit-making and hopes to be self-supporting and deserves support from every woodland owner and tree nurseryman in the country.

The Secretary of the association is Mr. E. S. J. Hinds, The Forest Tree Seed Association of England and Wales, 25 Savile Row, London, W. 1, and the annual subscription is one guinea.

Timber Research: Functions of the Forest Products Research Laboratory. A press release dated 17th December 1959 from the Department of Scientific and Industrial Research reads as follows. The 1958 arrangements referred to in the release were outlined at page 192 of volume xxxi of *Forestry*.

'The Council for Scientific and Industrial Research have reviewed the operation of the arrangements they made early in 1958, under which they asked the Timber Development Association to assume responsibility for certain aspects of timber research previously discharged by the Forest Products Research Laboratory. The Steering Committee for the Laboratory had become convinced that the new arrangements did not allow sufficient latitude to the Laboratory in the discharge of its essential duties, and that the division of functions between the Laboratory and any other research organization must be more flexible. They were convinced therefore of the need for a new approach to the problem of securing industrial support of work done for the immediate benefit of the timber trade (which was the aim of the earlier arrangements) and also to provide for the needs of the users—the home producer (including the Forestry Commission), the merchant, and the manufacturer. At the same time they felt it essential to maintain an adequate and well-balanced research team at the Forest Products Research Laboratory.

'The Research Council have therefore restated their general policy for the Forest Products Research Laboratory in the following terms:

'There is a continuing need in the national interest, both for research of a fundamental character on timber (but with ultimate practical applications) and for work of immediate benefit to the Forestry Commission and timber users. This work is best done at the Forest Products Research Laboratory with financial support from industry wherever possible. The Laboratory's programme should be co-ordinated with that of the Timber Development Association Research and Development Committee and/or of any Research Association which may be set up but should primarily be devised to ensure that the interests of government and the whole timber industry (producers and users, as well as merchants) are served to the best advantage.'

Director of Forest Products Research Laboratory. Mr. Henry Wooldridge, O.B.E., has been appointed Director of the Forest Products Research Laboratory to succeed Dr. F. Y. Henderson, C.B.E., who retires in October 1960.

Mr. Wooldridge, who has been a member of the F.P.R.L. Steering Committee since its formation, has spent most of his career at the Headquarters of the Department of Scientific and Industrial Research. In his present capacity as Head of Stations Division, he is responsible for Headquarters liaison with all the D.S.I.R. Laboratories, including the Forest Products Research Laboratory.

University Lecturer in Forest Utilization and Engineering, Oxford. Consequent upon the impending retirement of Colonel A. H. Lloyd, at the end of September 1960, there will be a vacancy for a University lecturer in Forest Utilization and Engineering in the Forestry Department, Oxford University. The salary is from £900 to £1,750 according to age and qualifications.

Candidates for the post should hold a University Degree in Forestry or an allied subject. Experience in the extraction and conversion of timber and a good general knowledge of field engineering are desirable. Specialist knowledge of the properties of timber and of modern utilization processes would be an asset.

Applications should reach the Professor of Forestry by 31st May 1960, from whom further particulars may be obtained.

Fifth World Forestry Congress, 1960. A fifth World Forestry Congress will take place at the University of Washington, Seattle, from 29th August to 10th September 1960. The discussion programme will cover all major fields of forestry including silviculture, forest management, genetics, protection, economics and policy, education, harvesting and utilization, the management of forest and range watersheds, and forest recreation. Inquiries may be made to Dr. I. T. Haig, Executive Secretary, c/o Office of International Conferences, Department of State, Washington 25, D.C., U.S.A.

Deputy Ranger of Windsor Great Park. It is announced from the Crown Estate Office that Sir Eric Savill, K.C.V.O., retires from 1st January 1960, and is succeeded as Deputy Ranger by Major Andrew Haig. Sir Eric Savill, who is appointed Director of Forestry and Gardens, Crown Estate, will continue to manage the Windsor Woodlands.

Midland Wood Society. In planning their fourth open conference which took place at Attingham Hall from 17th to 19th April 1959, the Society gave special thought to architects, engineers, and the building and furniture industries. The subject chosen was 'Problems and Principles of Timber Usage', and speakers included Sir Gordon Russell, Chairman of the Council for Industrial Design, and Mr. Philip Reece, Director of the Timber Development Association.

A British Tree-Ring Project. It is claimed that tree-ring analyses in America, Scandinavia, and in Germany have already thrown much light on the weather and climate required for the maximum growth of different species in different situations. The data collected have also proved useful in historical meteorology and in the archaeological dating of old building

timber. Co-operation is now invited from experts and amateurs who have the opportunity to study old trees to help establish a tree-ring project in Great Britain. Trees selected for analysis should have been grown in isolation and for the present should be either oak, elm, ash, or sweet chestnut. Analysis is either from tree-ring counts on the stumps of felled trees or from increment borer cores. Persons interested and able to help should write to Dr. D. Justin Schove, St. David's College, Beckenham, Kent, who calls attention to two items in the literature of the subject; *Geografiska Annaler*, Stockholm, 1954, pp. 216–30 and correction sheet; *Journal Medieval Archaeology*, London, 1957, pp. 78–94.

British Association Meeting, Cardiff, 31st August to 7th September, 1960. The Chairman of the Forestry subsection is T. R. Peace whose address is entitled 'The dangerous concept of the natural forest'. Other subjects include 'The afforestation of industrial waste' (J. Q. Williamson and T. Casson); 'The place of forestry in the economy of Wales' (G. B. Ryle and B. T. Wood); 'Studies in the developmental physiology of forest trees' (Professor Wareing, J. Black, A. Longman, J. Moorby). There will be excursions to St. Gwynno, Ebbw, Taf, Talybont, and Morganwg forests and to Tair Onen nursery. The Secretary is T. H. Owen and the local Secretary J. T. Fitzherbert.

Advisory Committee on Forest Research. The Forestry Commissioners have reconstituted their Advisory Committee on Forest Research. The following have agreed to serve as members for a period of four years from 1st January 1960.

Mr. F. C. Bawden, F.R.S., Director, Rothamsted Experimental Station.

Professor F. W. Rogers Brambell, F.R.S., Professor of Zoology, University College of North Wales, Bangor.

Professor R. Brown, F.R.S., Professor of Botany, University of Edinburgh.

Dr. D. J. Finney, F.R.S., Director, A.R.C. Unit of Statistics, Aberdeen.

Dr. J. W. Gregor, D.Sc., F.L.S., Director, Scottish Society for Research in Plant Breeding.

Dr. F. Y. Henderson, C.B.E., Director, Forest Products Research Laboratory.

Mr. G. V. Jacks, Director, Commonwealth Bureau of Soils.

Professor E. C. Mobbs, O.B.E., Professor of Forestry, University College of North Wales, Bangor.

Professor W. H. Pearsall, F.R.S., formerly Quain Professor of Botany, University of London.

Professor R. D. Preston, F.R.S., Professor of Plant Biophysics, University of Leeds.

Professor H. M. Steven, C.B.E., Professor of Forestry, University of Aberdeen.

Dr. A. B. Stewart, Director, Macaulay Institute for Soil Research.